Comparative Analysis and Energy Reduction Strategy for Nickel Mine Sites

2011

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A report submitted to the School of Engineering and Energy, Murdoch University in partial fulfilment of the requirements for the degree of Bachelor of Engineering

Murdoch UNIVERSITY

xstrata nickel

I declare that this project is my own account of my research and contains as its main content work, which has not previously been submitted for a degree at any tertiary education institution.

…………………………………….
Jane Elizabeth Woodroof

We are satisfied with the progress of this internship project and that the attached report is an accurate reflection of the work undertaken.

……………………………………..	…………………………………….
Industry Supervisor: David Niven	Academic Supervisor: Martin Anda

EXECUTIVE SUMMARY

Energy is becoming an increasingly important issue and is receiving increased interest due to the realization that the fossil fuel resources required for energy generation are finite and that climate change is linked to carbon emissions (Baños, *et.al* 2010). The Australian government has tried to address these issues by encouraging businesses to reduce their energy usage and carbon emissions through participating in the Energy Efficiencies Opportunities (EEO) program and by implementing financial incentives such as the impending carbon tax.

The purpose of this project was to analyse the energy usage at Xstrata Nickel Australasia's (XNA's) Cosmos and Sinclair Nickel operations then identify and evaluate energy efficient opportunities, as required by the EEO program. In addition, GHGs emitted by the sites were analysed to determine what would be required to move the sites towards carbon neutrality.

Cosmos' and Sinclair's energy usage and carbon emissions were analysed using their metering and data analysis information, which is summarized in the table below.

	Cosmos	Sinclair
Energy usage	964,338 GJ (0.96 PJ)	
	725,392 GJ (0.73 PJ)	238,945 GJ (0.24 PJ)
GHG emissions	60,665t$CO_{2\text{-}e}$	
	44,058 t$CO_{2\text{-}e}$	16,607 t$CO_{2\text{-}e}$
Data Monitoring	Power station report, fuel pricing spreadsheet, diesel EOM, gas trading invoice and energy mass balance (EMB)	Power station report, fuel pricing spreadsheet and diesel EOM

The potential opportunities for energy efficiency and carbon neutrality were identified and analysed through a multi-criterion analysis (MCA) and marginal abatement cost (MAC) curve. The outcomes of the MCA and MAC curve identified the top four initiatives to be implemented at Cosmos and Sinclair and identified the opportunities to be implemented for the recommended strategy. The top four initiatives and recommended strategy and their energy savings, carbon abatement, net benefits and payback periods are outlined in the following table.

	Site	Description	Energy Reduction	Carbon Abatement	Net benefits	Payback period
Top Four Initiatives	Cosmos	Spinning reserve reduction, reactive load sharing, ventilation telemetry and VSD on primary fans	100,184 GJ (14% reduction)	5,688 $tCO_{2\text{-}e}$ (13% reduction)	$9,759,167	≈11 months
	Sinclair	Fuel additives, more cyclones, guaranteed fuel economy and backfill transport	30,384 GJ (13% reduction)	1,982 $tCO_{2\text{-}e}$ (12% reduction)	$18,735,861	≈3 months
Recommended Strategy	Cosmos	Heat pumps, underground fans on shift change, high efficiency drives, compressed air leaks, ventilation telemetry, underground water recycling, VSD on primary fans, crushing and grinding review, de-lamping in camp, VSDs on air compressors, VSDs on blowers, mobile crusher efficiency, reduce material handling, lunch in village, LV fuel economy, spinning reserve reduction, combine concentrate hoppers and reduce load sharing	121,203 GJ (17% reduction)	6,998 $tCO_{2\text{-}e}$ (16% reduction)	$14,307,011	≈2.5 years
	Sinclair	Backfill transport, motelling in village, control loop tuning, primary fan blade maintenance, secondary fans in inactive headings, primary fan management, laundry fan and lighting, SAG mill motor air-con, more cyclones, heat pumps, flotation impellers, village lighting, mill control of power station, power reticulation, guaranteed fuel economy, streamline LV utilisation, fuel additives and water recycling underground	39,467 GJ (17% reduction)	2,531 $tCO_{2\text{-}e}$ (15% reduction)	$20,925,667	≈4 years

A carbon neutrality strategy, outlined in the table below, was also developed, which determined that the move towards carbon neutrality for Cosmos and Sinclair would not be feasible based on high capital costs, the current life of the mine and long payback periods.

	Site	Description	Capex	Payback period
Carbon Neutrality Strategy	Cosmos	Implementing energy efficiency opportunities first, then implementing renewable technologies (Solar PV – cheapest option)	$451 million	≈14 years
	Cosmos	Implementing energy efficiency opportunities first, then implementing offsetting opportunities (cheapest option)	$741,200	
	Sinclair	Implementing energy efficiency opportunities first, then implementing renewable technologies (Solar PV – cheapest option)	$134 million	≈7 years
	Sinclair	Implementing energy efficiency opportunities first, then implementing offsetting opportunities (cheapest option)	$281,520	-

Since the EEO program is an ongoing process, Cosmos and Sinclair will need to continue to assess their energy usage, to work towards improving their current data analysis systems, to identify potential energy efficient opportunities and determine their viability based on the energy savings and the net financial benefits and to report their results from the EEO process annually.

ACKNOWLEDGEMENTS

I would like to thank my academic supervisor, Martin Anda for his support, assistance and for all of his suggestions he gave throughout my project. I also would like to thank the support and assistance I received from Xstrata Nickel, in particular my industry supervisor David Niven, the environmental teams at Cosmos and Sinclair and numerous other employees who were willing to show me around and answer my questions. The opportunity to gain hands on experience working on a mine site and working with personnel and on the data rather than being external to the whole process was invaluable. I am incredibly thankful to Mike and Marc from Energetics who gave me the opportunity to work alongside them while they were on-site, to allow me to gain insight to the EEO process and for giving me advice for my project. I would also like to thank David Goodfield for his recommendations and assistance he gave throughout my project as well as the companies who provided assistance on pricing and application of technologies.

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GLOSSARY OF ABBREVIATIONS AND TERMS

CO_2	Carbon Dioxide
DRET	Department of Resources, Energy and Tourism
EEO	Energy Efficiency Opportunities
EMB	Energy mass balance
EOM	End of month
GHG	Greenhouse gas
GJ	Gigajoule
kL	Kilo-litre
KPI	Key Performance Indicator
kWh	Kilo-watt hour
L	Litre
MAC	Marginal Abatement Cost
MCA	Multi-criterion assessment
PH	Power house
PJ	Petajoule
PV	Photo-voltaic
SD	Sustainable development
t	Tonne
XNA	Xstrata Nickel Australasia
XNAO	Xstrata Nickel Australasia Operations

NOTE: The reporting periods mentioned in the report (i.e. 2010/2011) are from the 1st July until 30th June.

1.0 INTRODUCTION

Energy is becoming an increasingly important issue and is receiving increased interest due to the realization that fossil fuel resources required for energy generation are finite and that climate change is linked to carbon emissions (Baños, *et.al* 2010). This realization has led not only to increases in energy costs (refer to Appendix 10.1 for rises in costs for XNA), but also to action to reduce energy consumption and greenhouse gas (GHG) emissions. In Australia, action has already commenced with the government agreeing to reduce Australia's GHG emissions through the international agreement of the Kyoto Protocol. This has subsequently led to the implementation of government run energy and GHG reduction programs, as well as the government implementing financial incentives for businesses to reduce their carbon emissions through the impending carbon tax.

For businesses, these reduction programs, rising energy costs and impending carbon tax are considerable reasons to become accountable for energy consumption and to reduce their GHG emissions. Mining companies, as highly energy intensive activities (Kenjile 2004), have even more reason to become accountable due to the significant associated capital costs (Environment Australia 2002). A mining company that uses a substantial amount of energy and therefore is interested in reducing their energy consumption and GHG emissions is Xstrata Nickel Australasia (XNA) for their Cosmos and Sinclair Nickel operations.

1.1 Project Background

The first step for businesses to reduce dependency on fossil fuels is to introduce an energy efficiency program (Baños, *et al* 2010). Energy efficiency should be seen as a top priority to ensure a more sustainable energy future (Milo, *et al* 2010) and the Australian government has introduced the Energy Efficiencies Opportunities (EEO) program to assist businesses to achieve these goals by requiring them to identify, evaluate and report on cost-effective energy saving opportunities.

The EEO program is a statutory requirement under the *Energy Efficiency Opportunities Act 2006* (ComLaw 2006) and for businesses that use over 0.5 petajoules (PJ) of energy it is a legislative requirement to participate in the program. In the 2007-2008 reporting period, XNA exceeded the 0.5 PJ threshold triggering legislative participation in the program. 80% of the energy use by XNA must be assessed under the legislation which includes both their Cosmos and Sinclair operations, but excludes their Perth office. The EEO program operates on a five-year cycle which requires XNA to submit annual assessments to the federal Department of Resources, Energy and Tourism (DRET) by the 31 December each year. XNA submitted its first EEO report on December 31, 2010 and is required to submit their next EEO report on December 31, 2011.

The second step for businesses to reduce their dependency on fossil fuels would be looking towards carbon neutrality. Carbon neutrality is a total reduction of the net carbon emissions to zero (DECC 2009) and may be achieved by changing from current fossil fuel sources to renewable energy sources or through offsetting their carbon emissions.

Through introducing energy efficiency programs to reduce current energy usage and then looking towards carbon neutrality it can benefit businesses through cost savings, it reduces their dependency on fossil fuels and the business risks associated with it, it can contribute to better risk management and it can bring about better stakeholder relations through improved public image (Niederberger, *et.al* 2005).

1.2 Company Background

XNA is a high-grade nickel sulphide producer that operates in Western Australia. They own and operate two mining operations, Cosmos and Sinclair, and have an office located in Perth.

1.2.1 Cosmos Nickel Project

The Cosmos Nickel Project is located in the Northern Eastern Goldfields approximately 40 kilometres north-west of Leinster (Figure 1).

Construction of the project began in October 1999 and it achieved first nickel concentrate production in April 2000. The operations consist of two underground mines, Prospero (Helene decline) and Cosmos (Ilias decline), and an ore processing facility. Five high-grade massive sulphide deposits have been discovered to date within the vicinity of the Cosmos Nickel Operation, including Cosmos, Cosmos Deeps, Alec Mairs, Prospero and the Tapinos deposits. The bulk of production has been sourced from the Prospero and Alec Mairs ore bodies (Xstrata Nickel 2011). Prospero is currently being decommissioned and is expected to finish at the end of 2011. Cosmos is looking towards other ventures, has other ore bodies to source from (AM5, AM6 and Odysseys) and is expected to continue producing in 2017.

Ore processing is carried out using a conventional nickel sulphide flotation plant to upgrade the ore to approximately 18% nickel product in the final concentrate. The nickel concentrate is then transported via road train to Esperance Port for shipping to the Xstrata Nickel Sudbury smelter in Canada (Xstrata Nickel 2011).

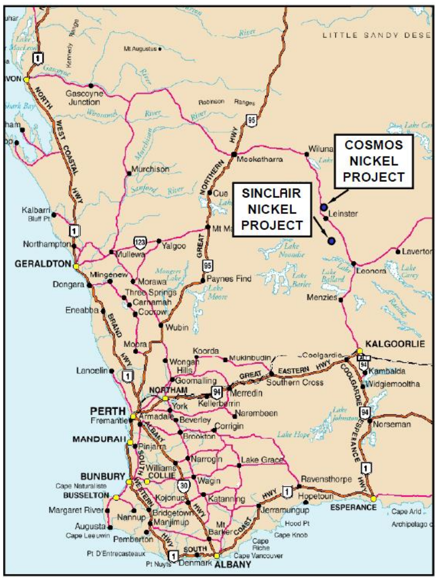

Figure 1: Location of the Cosmos and Sinclair Nickel Projects

1.2.2 Sinclair Nickel Project

The Sinclair Nickel Project is an open pit mine located approximately 100 kilometres south of the Cosmos Nickel Operation (Figure 1). Construction of the project began in December 2007 after discovery of deposits in November 2005, and it achieved first concentrate production in October 2008. The pit was completed in the third quarter of 2009 and the concentrator processed stockpiled materials until early 2010 when the project was placed on care and maintenance time. In April 2010, development of the underground operation was approved and the concentrator restarted in early August 2010 (Xstrata Nickel 2011). The current life of the mine is approximately 2 years (2013), however exploration is currently being undertaken which could potentially increase the life of the mine.

The nickel concentrate produced, along with that from Cosmos operations, is transported via road train to Esperance Port for shipping to the Xstrata Nickel Sudbury smelter in Canada (Xstrata Nickel 2011).

1.2.3 Business Strategy

Xstrata's business strategy is to continually work towards integrating sustainable development (SD) into the way they manage their business. The SD Framework is designed to ensure that each operation and project is managed consistently to the highest international and leading practice standards (Xstrata 2011) and comprises of Xstrata's Statement of:

- Business Principles – sets out the ethical framework for their activities globally and applies to each operation (Xstrata 2011);
- SD Policy – outlines Xstrata's environmental, health and safety commitments, as well as integrating commitment to communities and employees (Xstrata 2007); and
- SD Standards – 17 standards (Appendix 10.2 – the standards in the white cells align the Key Elements of EEO) that reflect Xstrata's SD ambitions and commitments (Xstrata 2008).

The hierarchy of the implementation of the SD framework from Xstrata plc through to XNA and its operations is illustrated in Figure 2.

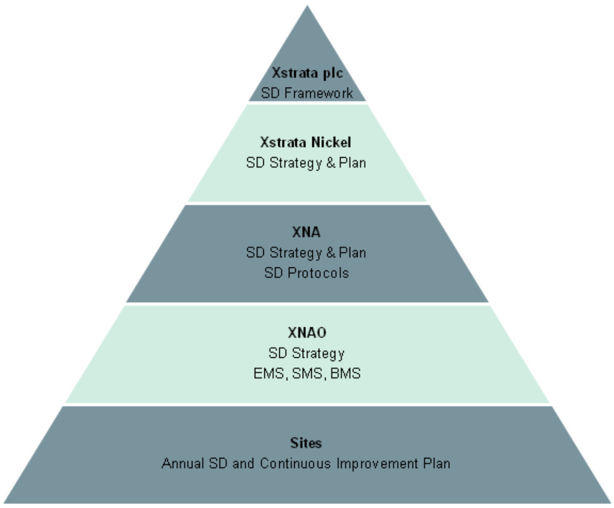

Figure 2: SD Document Hierarchy from XNA SD Management System

For XNA and its operations, looking at energy efficiency and reducing GHG emissions aligns with Xstrata's SD Policy (2007), in particular the goals to "continually improve the efficiency with which we use raw materials, energy and natural resources" and to "reduce our direct and indirect GHG emissions and work with other organisations, governments and groups to address climate change" (Xstrata 2007). The EEO program assists with achieving these goals by providing a process to continually assess and improve energy consumption.

Another strategy XNA uses to reduce their energy consumption and carbon emissions is through monitoring a range of key performance indicators (KPIs) to assess performance against SD targets and objectives. XNA's energy KPI targets, which are based off the previous years performance, for the site are:

- 5% reduction in energy used per tonne of concentrate produced;
- 5% reduction in carbon intensity per tonne of concentrate produced; and
- 5% reduction in diesel use per tonne of concentrate produced.

To assist in these site KPI targets being reached, individual department have their own KPI targets. By having targets for individual departments it encourages personnel participation as well as providing a way to identify which areas are not reaching their targets. The KPI targets for the individual departments are:

- Mining
    - 5% reduction in energy (PH) consumed per tonne hoisted; and
    - 5% reduction in diesel consumed per tonne hoisted.
- Mill
    - 5% reduction in energy (PH) consumed per tonne of concentrate produced.
- Administration
    - 5% reduction in energy (PH) consumed per man day.

1.3 Purpose & Objectives

The purpose of this project is to analyse the energy usage at XNA's Cosmos and Sinclair Nickel operations then identify and evaluate energy efficient opportunities, as required by the EEO program. In addition, GHGs emitted by the sites will be analysed to determine what would be required to move the sites towards carbon neutrality.

The objectives for the project, as requested by XNA, are:

- Undertake site visits to Cosmos and Sinclair sites to access energy information and engage with on-site personnel;
- Follow up on actions and recommendations arising from the XNA 2009/2010 Energy Efficiency Opportunity (EEO) report;

- Review the Energy mass balance tool developed and implemented by Energetics that was used to monitor and report on energy key performance indicators (KPIs) for Cosmos;
- Investigate all identified energy efficiency opportunities and shortlist a minimum of 3 for further investigation and implementation;
- Review site data gathering and metering equipment and provide a recommendations report for optimizing the system suitable for costing; and
- Complete government and public EEO report for the 2010/2011 period.

In addition to the objectives set by XNA, other objectives for the project are:

- Analyse GHG emissions emitted from Cosmos and Sinclair operations
- Investigate potential carbon neutrality options and suggest a strategy for moving the sites towards carbon neutrality

2.0 LITERATURE REVIEW

There have been many studies on energy consumption, resource reduction and the impact of climate change in Australia, including Garnaut's Climate Change Review (Garnaut 2008), Strategic Energy Initiatives Direction paper (Office of Energy 2011), and McKinsey & Company Australian Cost Curve for GHG Reduction report (McKinsey & Company 2008). These studies assist in acquiring a background understanding in Australian sector consumption trends (Appendix 10.3), the need for a reduction in energy usage and GHG emissions, and potential strategies for reduction.

Further information was sourced to gain a better understanding on EEO, to look at case studies on energy efficiency, renewable energy and carbon neutrality, as well as looking at specific data and studies done at Cosmos and Sinclair.

2.1 Energy Efficiency Opportunities

The DRET provides resource materials to businesses to assist them through the EEO process and to help them to understand their obligations. These documents are practical to obtain background information on EEO and energy mass balances (EMBs) in order to understand the requirements of the program and understand the EMB tool developed by Energetics. The register also is useful as it can be used to identify opportunities that could be applied at Cosmos and Sinclair Nickel projects

The key EEO documents include:

- *EEO Assessment Handbook* (DRET *a* 2010) – A guideline on planning, identifying and investigating opportunities and making business decisions throughout the EEO process;
- *EEO Industry Guidelines* (DRET *a* 2008) – Provides background information on EEO and assistance in the assessment process. The Industry Guidelines outlines key elements that are required during the EEO process which include: 1. Leadership, 2. People, 3. Information, Data and Analysis, 4. Opportunity Identification and Evaluation, 5. Decision Making, and 6. Communicating Outcomes. These key elements are vital for businesses to consider and implement during the EEO process. For XNA these key elements are already part of their business plan and are being implemented. The key elements can be linked to their SD Standards, which are outlined in Appendix 10.2 (with exception to the standards highlighted in the grey cells);

- *EEO Energy Mass Balance: Mining* (DRET *b* 2010) – A guidance document outlining key considerations and potential approaches for the development of an EMB for a mining operation in order to meet the requirements of the EEO program. Although the EMB has already been developed for Cosmos, it provides background information on how to develop an EMB and the information that needs to be included, so that a better understanding on how Cosmos' EMB works can be achieved;
- *Energy Savings Measurement Guide: How to Estimate, Measure, Evaluate and Track Energy Efficiency Opportunities* (DRET *b* 2008) – A guideline on determining potential opportunities and the potential energy savings associated with them; and
- *Significant Opportunities Register: Mining* (DRET *d* 2010)– A register that lists opportunities identified by mining operations who have participated in the EEO program between 2008 and 2009. Some of these opportunities may be able to be implemented at XNA's Cosmos and Sinclair operations.

2.2 Case Studies

2.2.1 Energy Efficiency

Whilst many of the potential opportunities will be identified from talking to personnel on site, since they are already aware of potential opportunities that should be implemented, other energy efficiency opportunities will be initially investigated to determine if they are applicable to Cosmos or Sinclair. Some of the resources that will be used are:

- *Energy Efficiency Processes and Measurement: Ausenco's Perspective* (Daniel and Lane 2008) – Discusses the efforts of a company to achieve energy efficiency, with particular focus on the milling process, and trying to create a business case for the application of the opportunities identified;
- *Energy Efficiency: Strategies for a Large Mining Operation in Western Australia* (Kenijle 2004) – The dissertation identifies strategies and potential opportunities for moving a large mining operation in Western Australia towards energy efficiency;
- *Energy Efficiency in China: the Business Case for Mining an Untapped Resource* (Niederberger, *et. al* 2005) – A study, in the context of the Chinese energy system, on how businesses can utilise energy efficient resources to gain competitive advantages and explains how to create a business case for energy efficiency; and

- *Energy Efficiency: Policy Measures to Reduce GHG Emissions* (Insight Economics 2006) – The article explores potential opportunities to improve energy efficiency in mine sites, including exploration, management, digital control of machinery, electricity generation efficiency, using alternative fuels and advanced mining approaches.

These resources provide insight into how to identify potential opportunities, they discuss common opportunities that exist and the importance of creating business cases to ensure that they are implemented. Another resource that was used was discussions with the consulting company, Energetics, to understand how to better create a business case and to ensure that the EEO program has a better chance of success when implemented

2.2.2 Renewable Energy

With rising energy costs and uncertainty surrounding future energy supply there has been numerous studies undertaken on renewable energy. A large number of these studies have been around the well established renewable technologies of solar PV and wind. These studies on the well established renewable technologies include Zahedi's (2010) study on solar PV and battery systems, Edward's (2010) thesis on the Murdoch PV system and Fidock's (2010) thesis on the stability of generation of a wind farm. Thesse studies look at how to optimise the current systems and identify potential issues with their operation.

A recent study that encompassed the majority of renewable technologies was CSIRO's "Unlocking Australia's Energy Potential" (2011), which expanded on the information in the "Australian Energy Resource Assessment" (Geoscience Australia and ABARE 2010). The "Australian Energy Resource Assessment" examined Australia's potential energy resources, including fossil fuels, uranium and renewable technologies, and CSIRO's study expanded on this through investigating the affordability, competitiveness and environmental standing of renewable technologies in Australia and the development stage that the technologies are at.

A study that specifically focussed on renewable energy technologies applied in mine sites, was undertaken by Nathan and Grano (n.d.) who researched emerging renewable energy technologies for a OZ mining in South Australia and whether they would be short term or long term alternatives compared to fossil fuels. A mine site that has currently implemented renewable technologies to supplement their energy usage is

Galaxy Resources at their Mt Caitlin mine site in Western Australia (Galaxy Resources. 2011). Many initial reports have described the hybrid, solar photo-voltaic (PV) and wind turbine, renewable energy system implemented at Mt Caitlin and reported Galaxy Resources' intentions to expand the renewable technologies to account for 100% of their energy usage to reduce their dependency on fossil fuels and the business risks associated with it (Martin 2011;Rampling 2011; Scanlon 2011; Thompson. 2011).

2.2.3 Carbon Neutrality

In Australia, the majority of the studies on carbon neutrality have been surrounding households or cities, and have investigated reducing of carbon emissions from a range of sources including electricity usage, waste production and transportation. Some of these studies on carbon neutrality have included Berry's (2010) thesis that investigated retrofitting a house and Sinclair's (2008) study that explored the effectiveness of carbon neutral projects in Australian environments.

In Australia, carbon neutral projects that are being implemented include the carbon neutral apartments at the Carlton Brewery site in Sydney (Jenkins 2011) and the management plan outlined by Maribyrnong council (2008) for trying to move the Melbourne suburb towards carbon neutrality. Internationally, there has been many examples of carbon neutrality including the Zero Carbon House project in Britain (Rea 2006), the Beddinton Zero Energy Development in Sutton and the Dongtan Eco-city in Shanghai (Sinclair 2008). All of these projects investigate different ways to reduce energy consumption and to account for carbon emissions.

2.3 Site Information

Data on energy usage was sourced from both Cosmos and Sinclair, including their power station reports, gas invoices, diesel reports and metallurgical data. The following outlines energy assessments that have been undertaken at the sites and the outcomes from those assessments.

2.3.1 Cosmos Nickel Project

At Cosmos, work has already been undertaken to identify energy usage and potential energy efficiency opportunities as required by EEO. In September 2009 a Level 1 energy audit was conducted by consulting company Climate Changers Now from 2007 until 2009. After reviewing Cosmos' energy usage the audit identified that XNA exceeded the 0.5PJ threshold and therefore was required to participate in the EEO program. The audit also investigated potential energy efficient opportunities that could be implemented to reduce their energy usage.

Following the identification of participation in the EEO program by Climate Changers Now in 2009, the consulting company Energetics developed an energy mass balance (EMB) for Cosmos for 2010. The EMB was developed to assist in identifying energy flows and major energy users on site. The site usage for the 2009/2010 period was then assessed and 26 potential energy efficiency opportunities were identified, which were analysed according to the accuracy of their net energy savings and financial benefits. Following the assessment conducted by Energetics XNA submitted its first EEO report to DRET on 31 December 2010. The potential opportunities that were identified from the assessment are being reassessed due to significant changes in operations.

2.3.2 Sinclair Nickel Project

Sinclair was not assessed in the 2009/2010 EEO report as it was during a period of care and maintenance. In the third quarter of 2011, Sinclair assessed their energy usage and potential energy efficiency opportunities, with the assistance of Energetics, as required by the EEO program and will be included in the EEO report to be submitted on 31 December 2011.

3.0 METHODOLOGY

3.1 Approach

The approach that will be taken in this project is to utilise a number of research and data analysis techniques. The techniques that were used and the process involved in the completion of the report are:

- Literature Review – Review information on the EEO program, energy efficiency, renewable energy and carbon neutrality through journals, books and internet databases;
- Data Analysis – Review metering data, EMBs and audits undertaken at Cosmos and Sinclair and collaborate with Energetics during their assessment of Sinclair in August. The information sourced from metering data and audits at Sinclair will be compared to the information obtained by Energetics in their assessment of Sinclair for the 2010/2011 period to check for inconsistencies;
- Interpretation of Data – Develop appropriate graphs, flow diagrams and tables to effectively display energy consumption for Cosmos and Sinclair;
- Identify Potential Opportunities – Identify opportunities from literature reviews, through discussions with personnel and through the EEO workshop that will be held by Energetics. The energy efficient opportunities will be based on preliminary findings from Energetics;
- Analyse Opportunities – Opportunities will be analysed for their feasibility through a multi-criterion assessment (MCA) and through a MAC (marginal abatement cost) curve. The multi-criterion assessment will investigate the opportunities based on economic, environmental, social and technical criteria and will involve XNAs Risk Assessment framework. The MAC curve will investigate the opportunities based on their financial and carbon abatement benefits;
- Recommend Strategy – Determine a strategy for the recommended opportunities to implement, a strategy for the sites to achieve carbon neutrality and a strategy for improving data metering and analysis;
- EEO Reporting – Complete the EEO report that is required for the second report for the 2010/2011 period. Also complete a government report which outlines in further detail the information in the public report;
- Conclusion and Recommendations – Provide a summary of the project and recommendations for further study for the project.

3.2 Scope

The scope of this project is to look at energy usage and GHG emissions at Cosmos and Sinclair, which will be limited towards energy used and emissions from electricity generation and energy used in diesel. Emissions from the waste water treatment plant and energy usage from transporting goods or employees to site have not been included in the scope for this project.

3.3 Assumptions

The assumptions that have been made in this project are that the data calculated from the information sourced is a reasonably accurate representation of the energy usage at Sinclair and Cosmos. Implementation costs for opportunities has not been included as it is assumed that personnel on site will be able to do the fittings themselves. Transportation costs has also not been included as it was assumed that items can be backlogged onto trucks that are already travelling from Perth to Cosmos or Sinclair.

3.4 Limitations

Due to the complex nature of the mine sites there are some limitations to the project and in the analysis of the potential opportunities. The limitations for the project are that the analysis of energy consumption is limited to the information available, the potential opportunities investigated will be limited to ones that are past the development stage and the opportunities investigated are only an initial analysis therefore further evaluation of the opportunities will need to be investigated for their viability.

Factors that are difficult to include in the analysis of the opportunities include future structural changes to the operations and cost increases/decreases to energy.

4.0 SITE ANALYSIS

4.1 Energy Consumption Analysis

An energy assessment was undertaken at Cosmos and Sinclair through an analysis of metering information (as outlined in Table 4), energy mass balance tools and KPI spreadsheets. Both sites have similarities in their operation, however Cosmos is a bigger site and therefore uses more energy and they also have natural gas as one of their energy sources. The energy usage, electricity generation and consumption, vehicles and equipment diesel use and GHG emissions for Cosmos and Sinclair is summarised in Table 1, and the differences between energy use is evident.

A detailed analysis of energy usage for each site is outlined in section 4.1.1 Cosmos Nickel Project and section 4.1.2 Sinclair Nickel Project.

Table 1: Assessment of Energy Usage for Cosmos and Sinclair for 2010/2011

	Cosmos	Sinclair
Energy		
Energy usage	964,338 GJ (0.96 PJ)	
	725,392 GJ (0.73 PJ)	238,945 GJ (0.24 PJ)
Sources	Natural Gas – supplied by Gas Trading directly to power station Diesel Fuel – supplied by tanker trucks into the Cosmos and Prospero fuel farms	Diesel Fuel – by tanker trucks into the fuel farm
Electricity		
Generation & Supply	12 x 1,000kW (1,250kVA) V16 diesel gensets generates and supplies electricity to the whole site. 9 gensets run on natural gas and diesel (approximately 70% and 30% respectively). 3 gensets which begun supplying electricity to the site in March and May 2011 run solely on diesel Gensets are hired through a contract with KPS - costs $239,135/month	8 x 1,000kW (1,250kVA) V16 diesel gensets generates and supplies electricity to the whole site. All gensets run on diesel, since that is only energy source. Gensets are through a contract with KPS - costs $137,120/ month
Generation for 2010/2011 period	47.0GWh of electric0ity (169,364GJ of energy)	17.8GWh of electricity (63,993GJ of energy)
Energy consumption	Diesel: 4,311,150L Natural Gas: 349,869 GJ	Diesel: 4,629,776L
Powerhouse Efficiency	32%	36%

Vehicles & Equipment		
Vehicle types	• Heavy vehicles (Haul trucks, dump trucks, excavators, graders, loaders, service trucks) • Light vehicles • Drill rigs and jumbos • Other (bus, forklift, crusher, dewatering pumps, compressor, charge up, screen)	
Usage for 2010/2011 period	5,417,445 L (209,113 GJ)	1,560,523 L (60,236 GJ)
GHG Emissions		
Total emissions for 2010/2011 period	60,665t$CO_{2\text{-}e}$ Potential cost with impending carbon tax (\$23/t$CO_{2\text{-}e}$) = \$1,395,295	
Emissions for 2010/2011 period	44,058 t$CO_{2\text{-}e}$	16,607 t$CO_{2\text{-}e}$
Emissions for 2009/2010 period	40,245 t$CO_{2\text{-}e}$	9,717 t$CO_{2\text{-}e}$

4.1.1 Cosmos Nickel Project

Cosmos Nickel Project is the bigger energy user with a total energy use of 0.73 PJ which makes up 75% of the total usage between sites. The site uses energy for electricity generation (natural gas and diesel) and for equipment (diesel). Figure 3 illustrates the breakup of energy usage and it is evident that there is approximately equal split between total diesel and gas usage on site. From the energy usage in Figure 3, 29% of energy usage is attributed to equipment and 71% is for electricity usage.

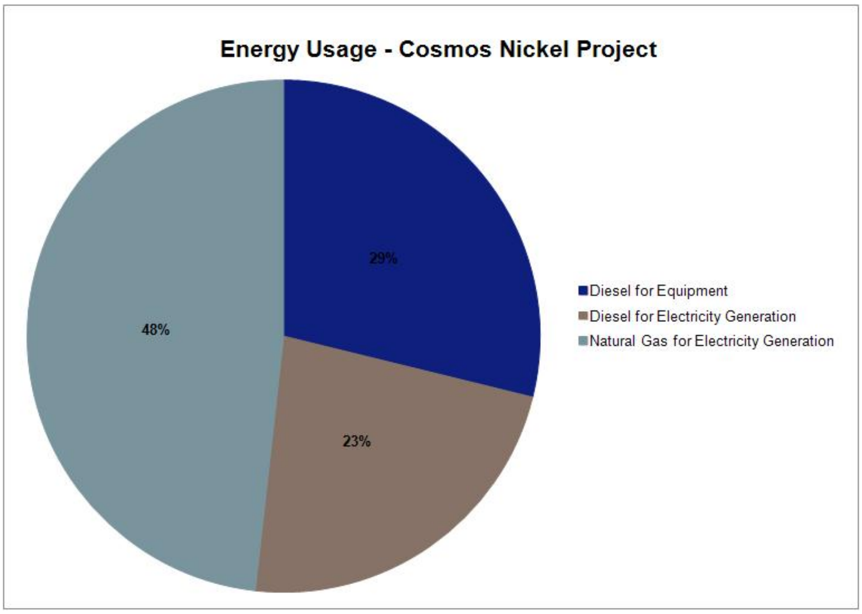

Figure 3: Energy Usage for Cosmos Nickel Project for 2010/2011

The main areas that are supplied energy as identified through the metering within the site are the underground mines (Prospero and Cosmos), the processing plant, the village and administration. The distribution of electricity consumption between these areas are shown in Figure 4. From this figure it is evident that the Cosmos and Prospero mines and the processing plants are large energy users with the village and administration collectively accounting for only 7% of the energy usage. Unaccounted power accounts for 6% of the energy usage, which occurred through metering and sub-metering (Plant feeder is meter and the sub-meters are Village, plant and administration). The fluctuations for electricity consumption for each month during the 2010/2011 period for the different areas for Cosmos is illustrated in Figure 5.

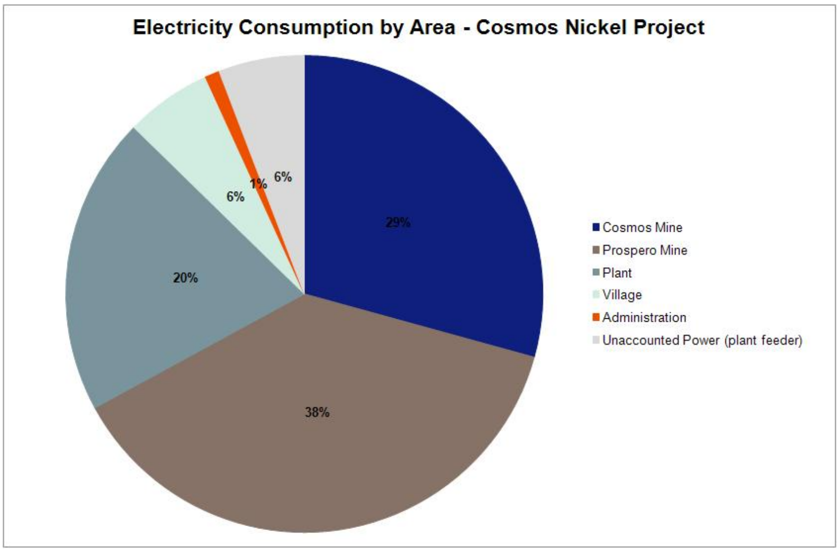

Figure 4: Cosmos Electricity Consumption by Area for 2010/2011 Period

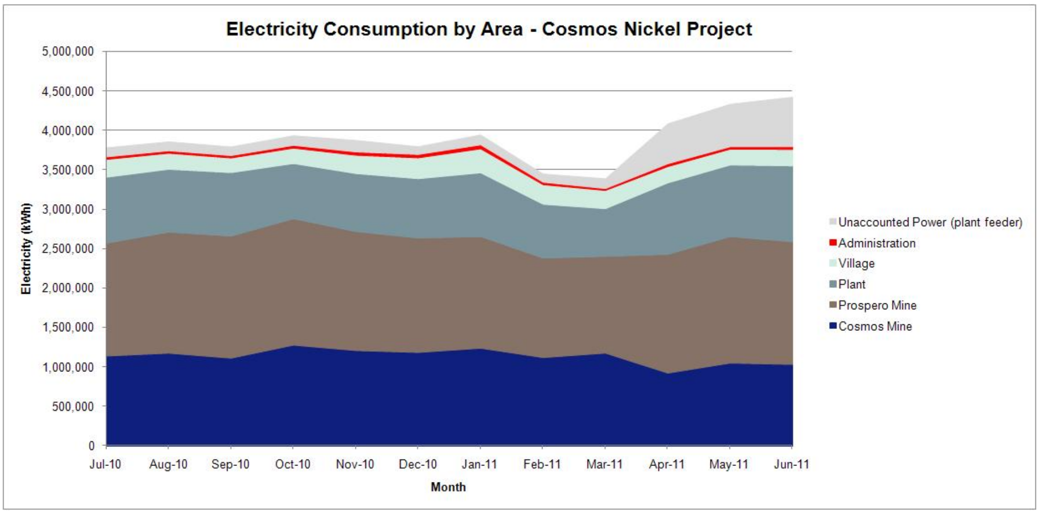

Figure 5: Cosmos Nickel Project Electricity Consumption by Area for 2010/2011 Period

The energy flows around the site are illustrated in the Sankey diagram (Figure 6), which includes mass flows (ore, concentrate, tails and scats). From this diagram there is also evidence of unaccounted power between the meters and sub-meters which may be due to distribution losses.

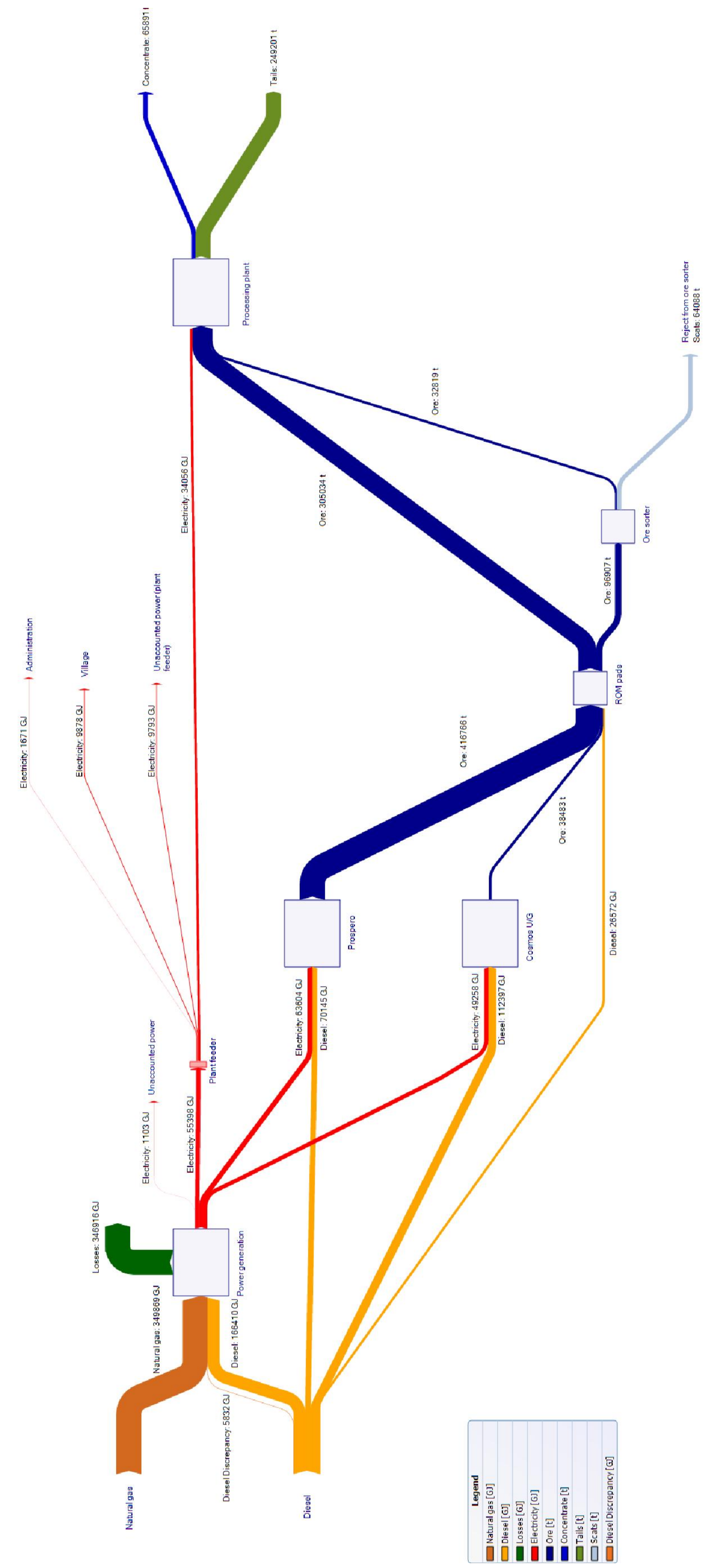

Figure 6: Sankey Diagram for Cosmos Nickel Project for the 2010/2011 Period

For electricity generation on site, Cosmos has 12 diesel gensets that run on diesel and natural gas, with the exception of 3 generators that recently were commissioned and run on diesel. The energy consumed and generated, and the efficiency of the generators for each month over the 2010/2011 period is illustrated in Figure 7, and Figure 9 shows the flows for of energy and outlines the load of each genset. Figure 8 illustrates each genset for a typical month (October 2010). From these figures it is evident that there are major losses from the gensets which are mainly in the form of lost heat, load shifting and some minor friction and transmission losses. The efficiency of the power station is approximately 32% which is within the expected range for this type of power station.

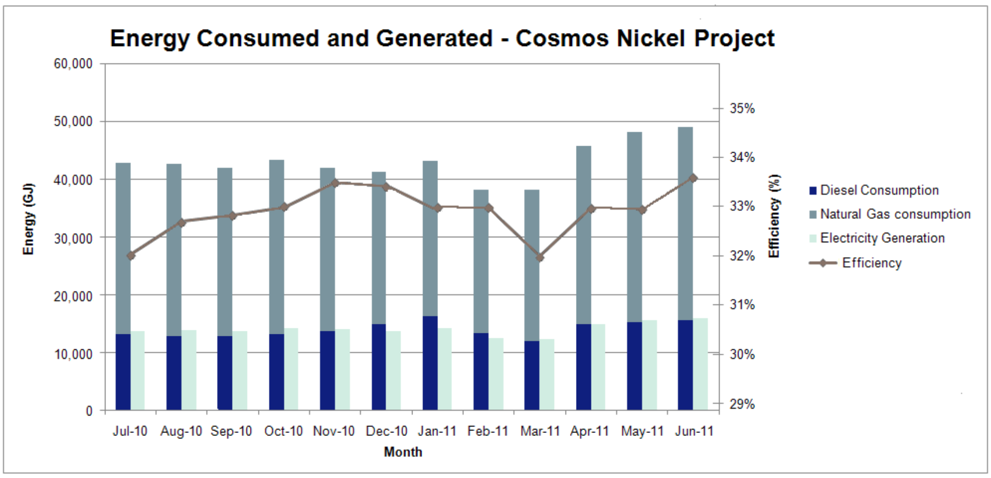

Figure 7: Cosmos Energy Consumed and Generated by the Power Station each Month for 2010/2011 Period

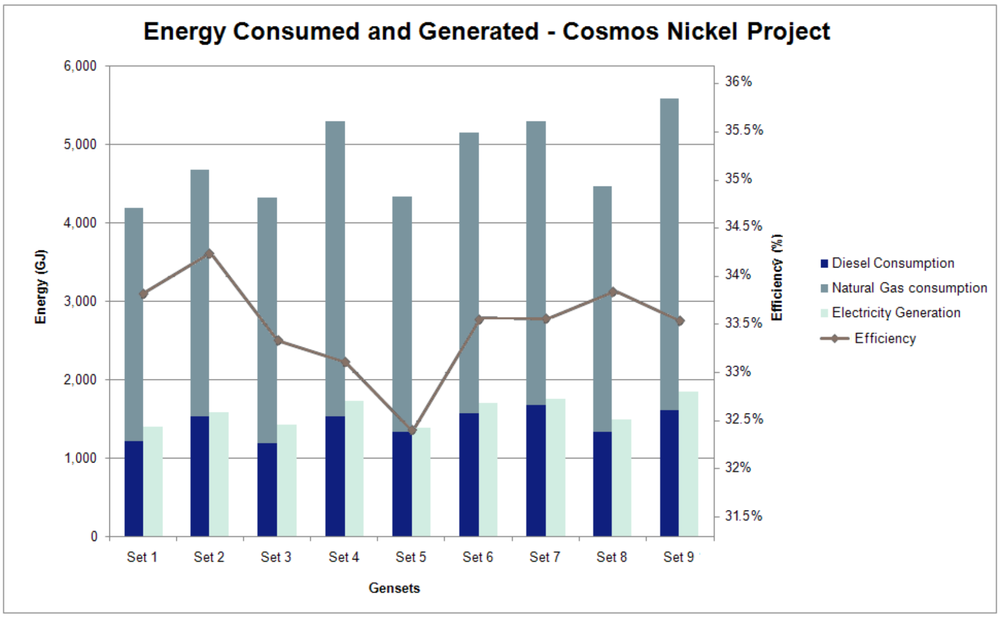

Figure 8: Energy Consumed and Generated in each Genset of the Power Station for a Typical Month (October 2010)

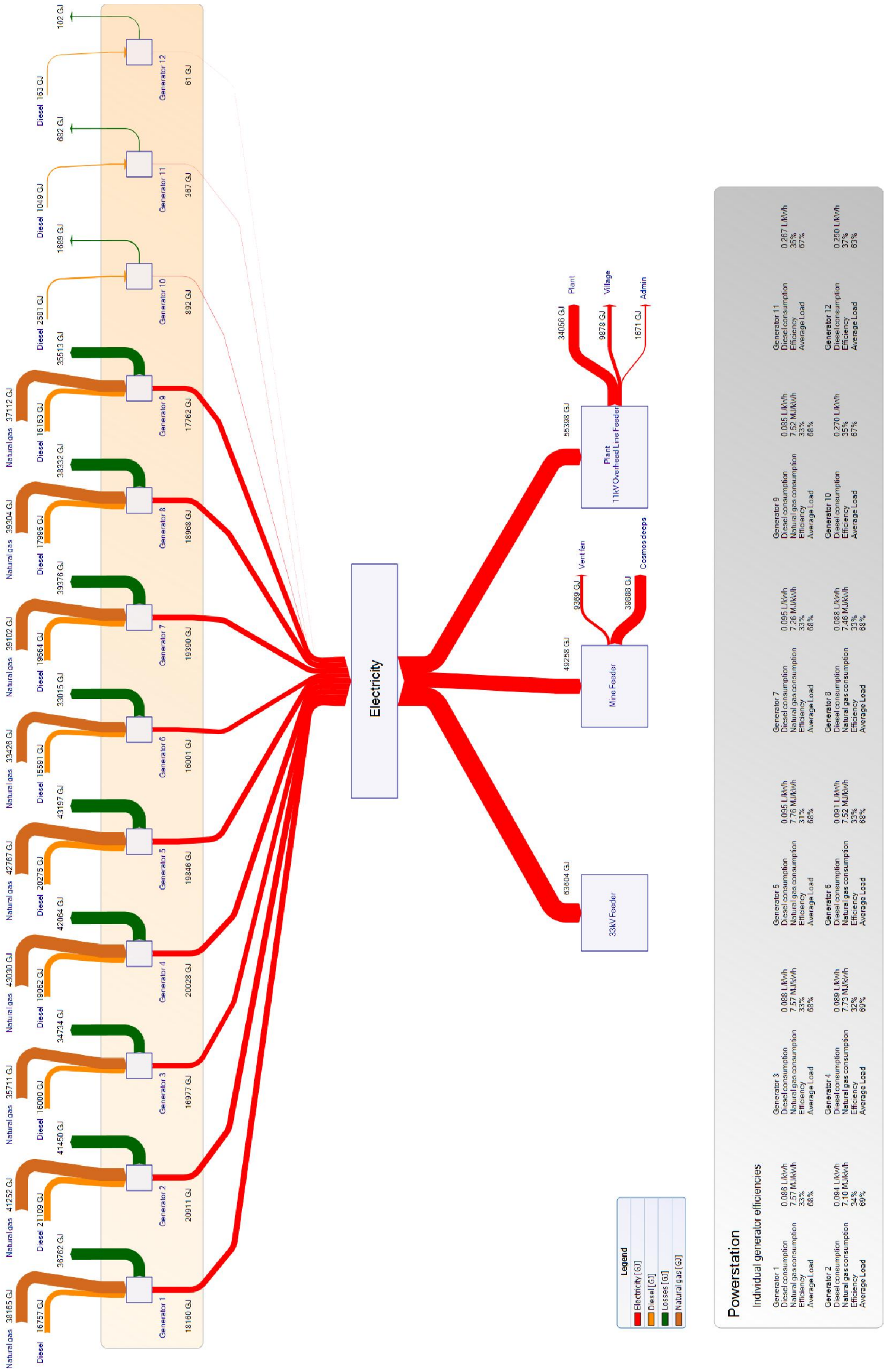

Figure 9: Sankey Diagram for Cosmos Power Station for the 2010/2011 Period

For equipment use on site, Cosmos uses vehicles for hauling and filling, light vehicles for general access around site, service vehicles, drills and other equipment, as shown in Figure 10. From Figure 10 it is apparent that the majority of the energy usage is for haulage and filling, which accounts for 58% of equipment diesel usage. Light vehicles accounts for a small percentage of the total equipment diesel usage at 9%. Figure 11 illustrates the fluctuations in diesel, between 379kL and 502kL over the 2010/2011 period.

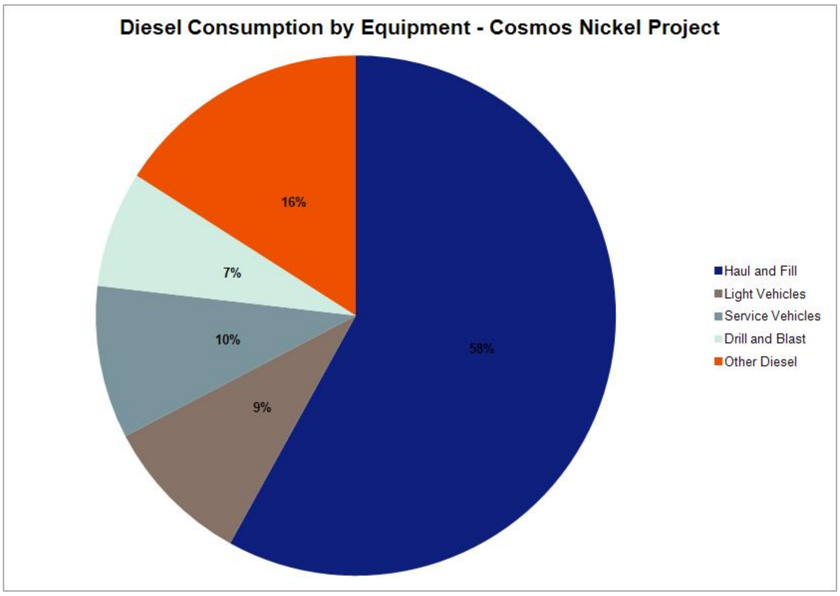

Figure 10: Diesel Consumption by Equipment for Cosmos for the 2010/2011 Period

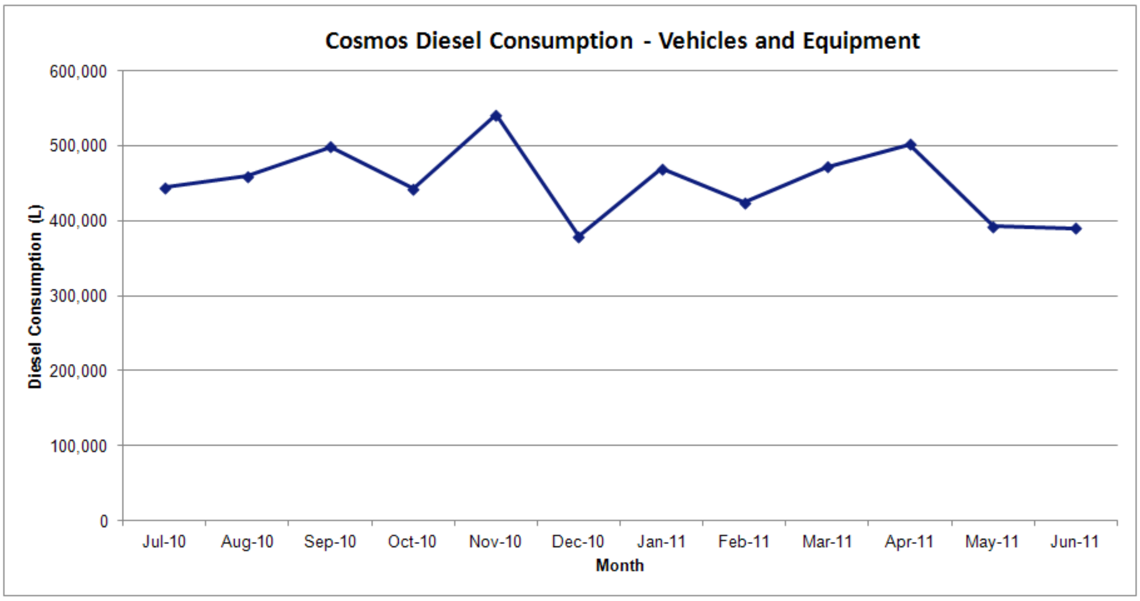

Figure 11: Diesel Consumption for Cosmos for the 2010/2011 Period

For equipment on site there are no individual meters that indicate where the large electricity users are. Since underground accounts for a large percentage of the total site electricity use, estimates were made on electricity use based off the kilo-watt rating of the equipment underground, as shown in Figure 12. This figure shows that the primary and secondary fans and the pumps account for a large percentage of energy usage.

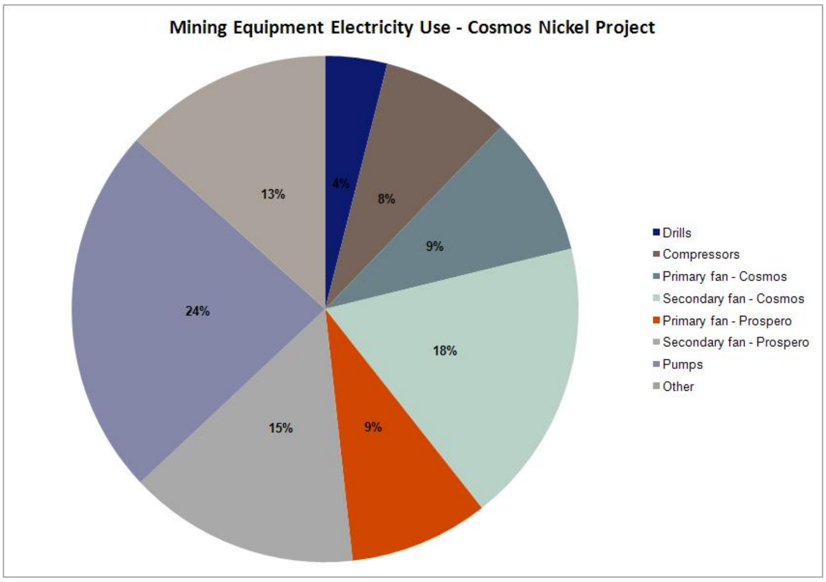

Figure 12: Estimates of Electricity Use for Mining Equipment

The KPIs for Cosmos over the 2010/2011 are shown in Table 2 where it can be seen from the orange highlighted cells that Cosmos is not reaching their targets for energy reduction and highlights the importance of energy efficiency projects to reduce their energy usage. The reason for not reaching their targets may be attributed towards the changes in the operations with changes from massive to disseminated ore which resulted in less concentrate in the ore hauled and the addition of a ball mill to the sag mill in the processing plant.

Table 2: KPIs for Cosmos for the 2010/2011 Period including Targets for 2010 and 2011

	Units	2010 Goal	2011 Goal	Jul -10	Aug -10	Sep -10	Oct -10	Nov -10	Dec -10	Jan -11	Feb -11	Mar -11	Apr -11	May -11	Jun -11
Site															
5% reduction in energy used per tonne of concentrate produced	kWh/t	652	620	501	576	601	910	535	718	596	680	1252	883	819	675
5% reduction in carbon intensity per tonne of concentrate produced	$t(CO_{2-e})/t$	0.602	0.572	0.471	0.535	0.599	0.822	0.553	0.596	0.561	0.661	1.41	0.956	0.865	0.794
5% reduction in diesel use per tonne of concentrate produced	L/t	-	-	* data not collected						199	230	131	177	103	141
Mining															
5% reduction in energy (PH) consumed per tonne hoisted	kWh/t	45.4	43.1	41.2	43.8	41.4	48.8	37.2	45.2	44.7	52.5	58.2	51.4	46.4	45.9
5% reduction in diesel consumed per tonne hoisted	L/t	4.68	4.44	4.63	4.25	4.91	4.78	4.98	2.40	4.40	2.07	6.80	6.24	3.83	4.33
Mill															
5% reduction in energy (PH) consumed per tonne of concentrate produced	kWh/t	137	131	114	122	131	166	105	146	126	139	231	223	194	170
Administration															
5% reduction in energy (PH) consumed per man day	kWh/ man day	34.5	32.7	31.4	29.0	27.7	25.5	32.7	38.0	42.9	32.1	25.7	28.8	26.7	29.8

Data exceeds goal
No baseline data

4.1.2 Sinclair Nickel Project

Sinclair Nickel Project is a smaller operation that Cosmos with a total energy usage of 0.24 PJ which accounts for 25% of the total usage between sites. The site uses energy for electricity generation and for equipment with the energy source being diesel. Figure 13 illustrates the breakup of energy usage, where it is evident that electricity generation accounts for a large percentage of the total diesel usage. The percentage of energy usage at Sinclair when compared to Cosmos for energy for electricity generation and energy for equipment is similar, with Cosmos' breakup being 71% and 29% respectively, and Sinclair's breakup being 75% and 25% respectively.

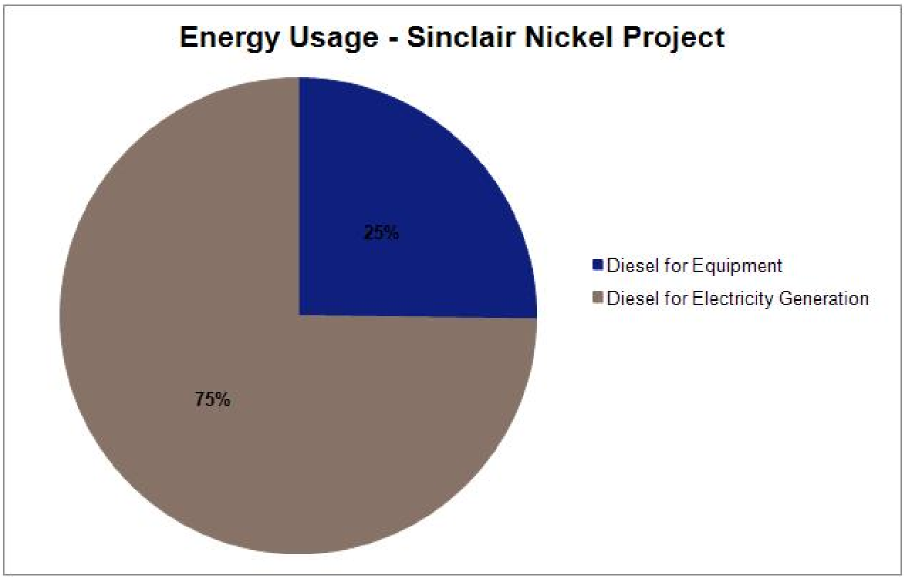

Figure 13: Energy Usage for Sinclair Nickel Project for 2010/2011

The main areas that are supplied energy within the site, as identified through the metering information, are the underground mine, administration, treatment plant, the village and the maintenance workshop. The distribution of electricity consumption between these areas are shown in Figure 14. From this figure it is evident that the treatment plant accounts for a significant percentage of the total energy use with 58% and the underground mine including the administration offices accounting for a substantial percentage with 34%. Unlike Cosmos, there was no unaccounted power between the sub-meters since the underground and administration offices are not metered and determined from subtracting the sub-meters of the village and the maintenance workshop from the powerline meter. For comparing Cosmos' electricity consumption to Sinclair's, the villages use similar amounts of electricity with 6% and 7.7% respectively. The mines use similar amounts of electricity when Cosmos's mines are assessed individually, with Cosmos' consumption 29%, Prospero's consumption

38% and Sinclair's mine using 34%. For the processing plant, the percentage consumptions are significantly different with Cosmos' plant accounting for 20% of electricity consumption and Sinclair's accounting for 58%.

The fluctuations for electricity consumption for each month during the 2010/2011 period for the different areas for Sinclair is illustrated in Figure 15.

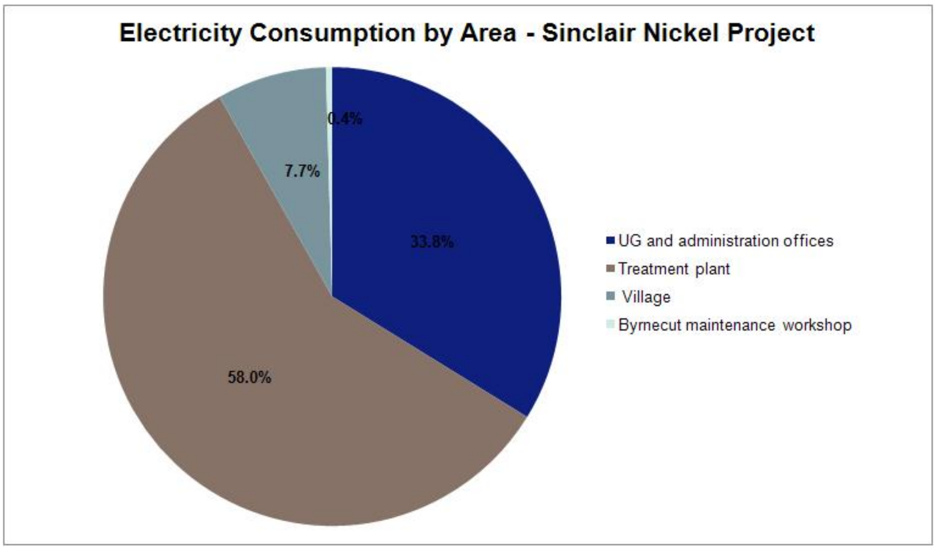

Figure 14: Sinclair Electricity Consumption by Area for 2010/2011 Period

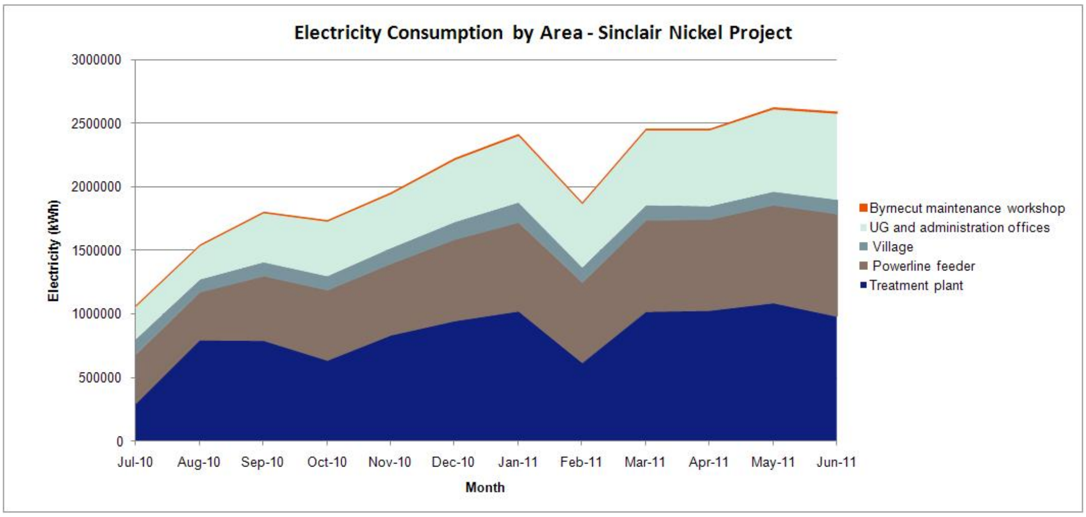

Figure 15: Sinclair Nickel Project Electricity Consumption by Area for 2010/2011 Period

The energy flows around the site are illustrated in the Sankey diagram (Figure 16), which includes mass flows (ore, concentrate, tails and waste rock). There was unaccounted power identified from the electricity coming out of the power station and power accounted to each of the meters, similar to Cosmos, which may also be accounted to distribution losses.

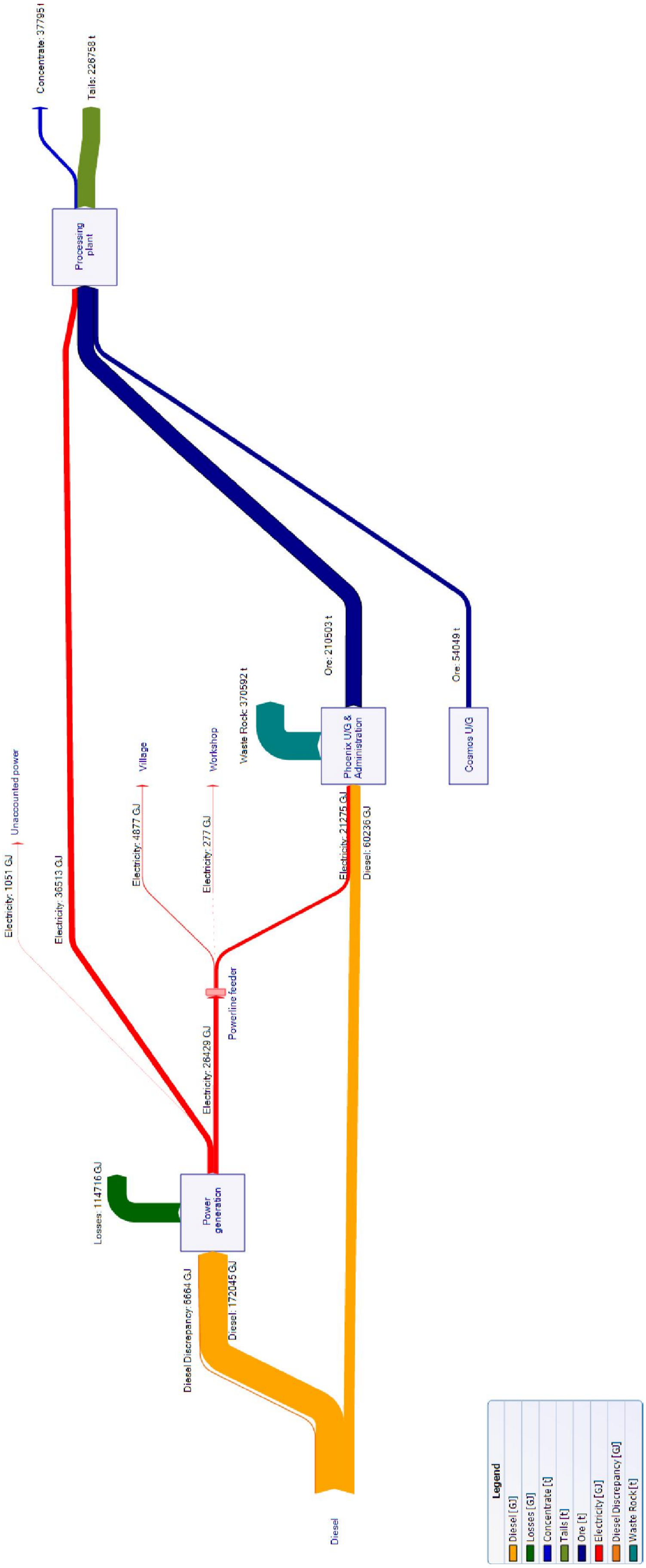

Figure 16: Sankey Diagram for Sinclair Nickel Project for the 2010/2011 Period

For electricity generation on site, Sinclair has 8 diesel gensets that run on diesel. The energy consumed and generated, and the efficiency of the generators for each month over the 2010/2011 period is illustrated in Figure 17 (diesel consumption for August is missing due to data not being recorded), and Figure 19 shows the flows for of energy and outlines the load of each genset. Figure 18 shows each genset for a typical month (March 2010). Similar to Cosmos, it is evident from these figures that there are major losses from the gensets which are similarly due to lost heat, load shifting and some minor friction and transmission losses. The efficiency of the Sinclair power station is approximately 36% which is within the expected range for this power station. From Figure 18, it can also be noted that only half of the genset capacity appears to be used, which is due to the power station being sized larger than what was required at Sinclair.

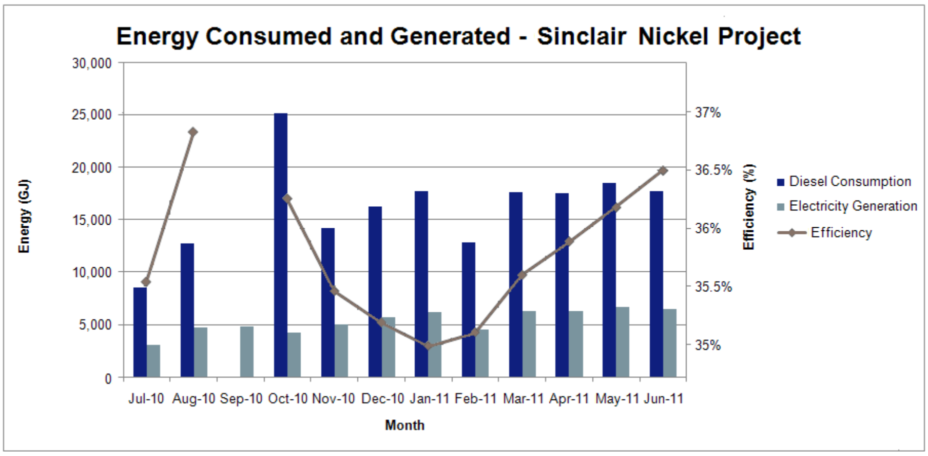

Figure 17: Sinclair Energy Consumed and Generated by the Power Station each Month for 2010/2011 Period

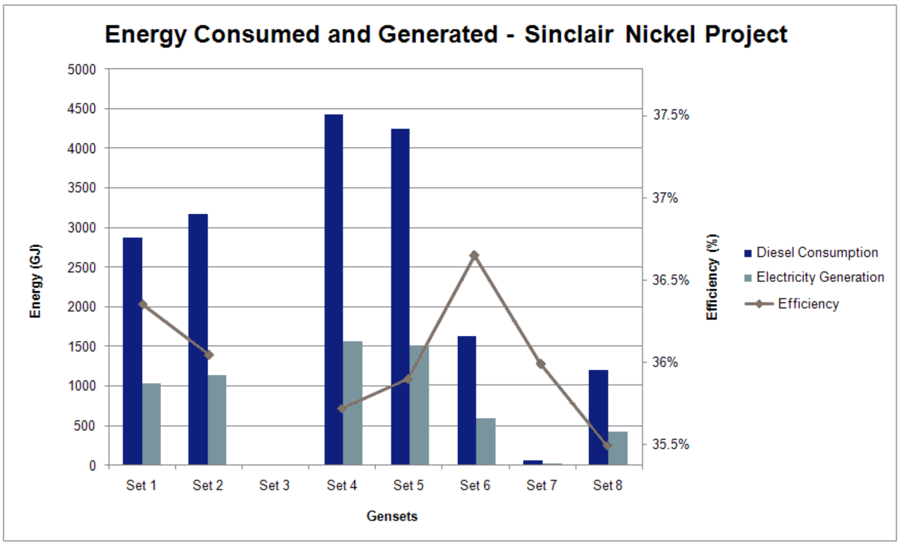

Figure 18: Energy Consumed and Generated in each Genset of the Power Station for a Typical Month (March 2010)

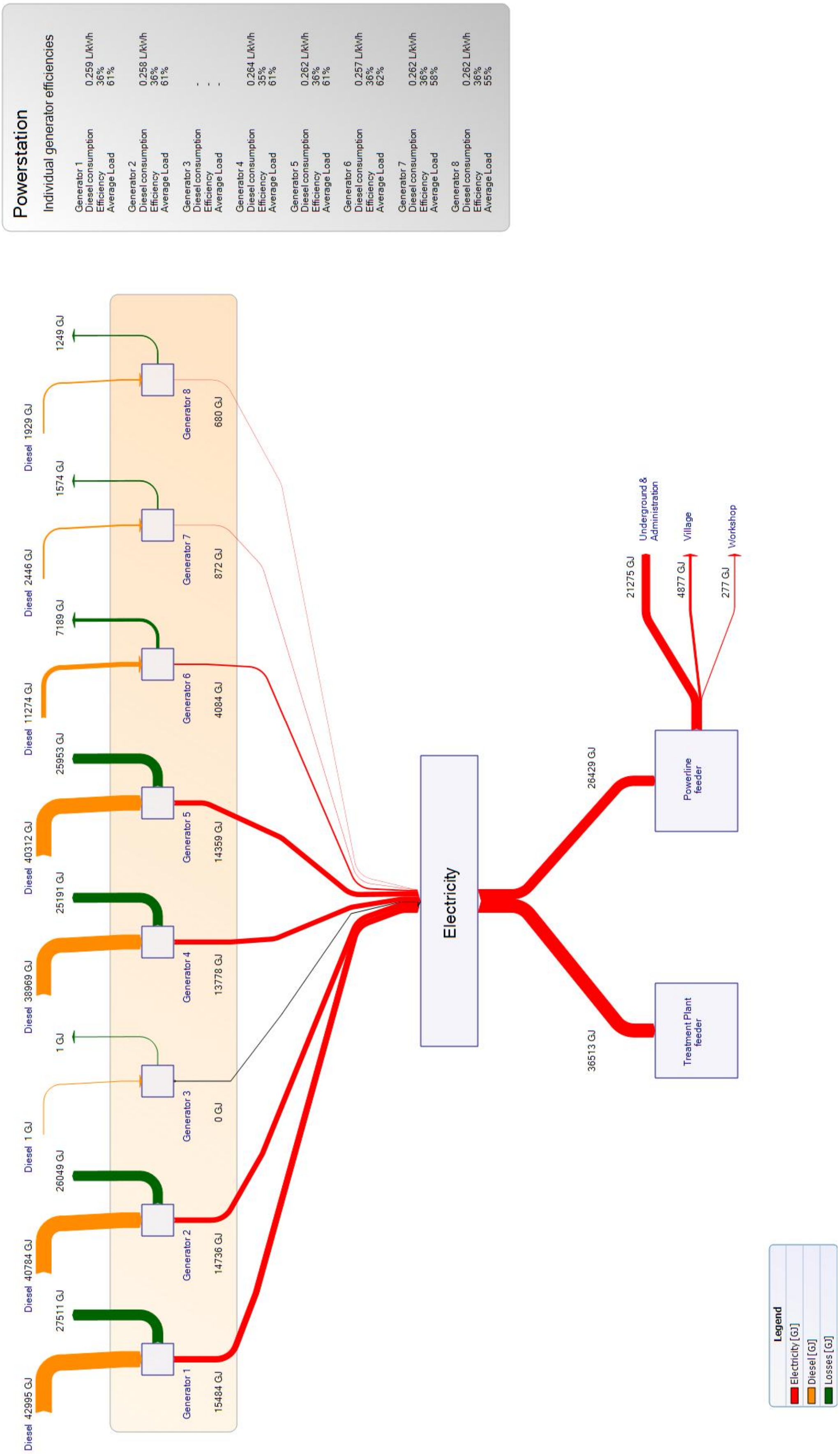

Figure 19: Sankey Diagram for Sinclair Power Station for the 2010/2011 Period

For equipment use on site, Sinclair uses vehicles for hauling and filling, light vehicles for general access around site, service vehicles, drills and other equipment, as shown in Figure 20. From Figure 20, it is apparent that the majority of the energy usage is for haulage and filling, which accounts for 58% of equipment diesel usage. A difference between the data for Cosmos and Sinclair is that Sinclair has a significantly larger percentage of diesel usage for light vehicles with 24%, as opposed to Cosmos which only had light vehicles accounting for 9% of the total usage. Figure 21 illustrates the fluctuations in diesel, between 79kL and 242kL over the 2010/2011 period. In February 2010 there was a drop of diesel usage due to flooding at that time which meant a restriction of getting the diesel trucks to site, and in July 2010 the site was in a period of care and maintenance and no concentrate was produced in that month.

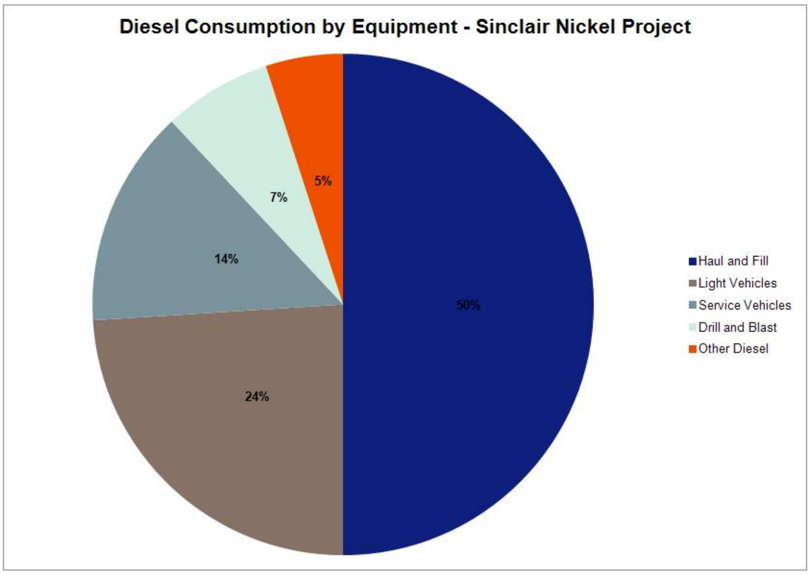

Figure 20: Diesel Consumption by Equipment for Sinclair for the 2010/2011 Period

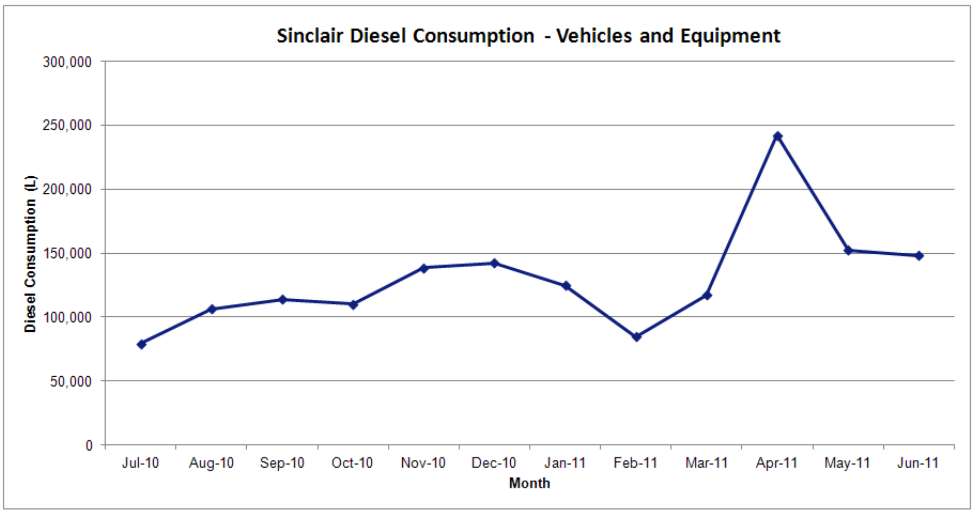

Figure 21: Diesel Consumption for Sinclair for the 2010/2011 Period

The KPIs for Sinclair over the 2010/2011 are shown in Table 3 where it can be seen that similar to Cosmos there is a fair amount of orange highlighted cells which indicates that the for the month they exceeded their goal. It should be noted however that Sinclair are in the process of collecting their baseline data and the baseline data that was used from 2010 for their 2011 goal only used 5 months due to the period of care and maintenance. Despite the baseline data still being collected it is still important that Sinclair develops strategies to reduce their energy usage.

Table 3: KPIs for Sinclair for the 2010/2011 Period including Targets for 2010 and 2011

	Units	2010 Goal	2011 Goal	Jul -10	Aug -10	Sep -10	Oct -10	Nov -10	Dec -10	Jan -11	Feb -11	Mar -11	Apr -11	May -11	Jun -11
Site															
5% reduction in energy used per tonne of concentrate produced	kWh/t	-	420	-	294	416	651	444	540	541	640	479	438	345	395
5% reduction in carbon intensity per tonne of concentrate produced	$t(CO_{2-e})/t$	-	-	* data not collected											
5% reduction in diesel use per tonne of concentrate produced	L/t	-	-	-	103	151	203	163	166	199	230	131	177	103	141
Mining															
5% reduction in energy (PH) consumed per tonne hoisted	kWh/t	-	8.16	9.01	7.70	12.4	10.9	5.63	9.41	15.0	24.8	9.66	9.68	9.53	15.7
5% reduction in diesel consumed per tonne hoisted	L/t	-	1.68	1.25	1.86	2.32	1.71	1.28	2.13	2.97	3.59	1.40	3.08	1.95	2.89
Mill															
5% reduction in energy (PH) consumed per tonne of concentrate produced	kWh/t	-	255	-	201	255	351	267	323	323	319	282	259	203	218
Administration															
5% reduction in energy (PH) consumed per man day	kWh/ man day	-	36.6	2.31	38.4	37.4	34.6	39.8	42.3	52.8	43.9	41.2	33.7	31.8	33.4

Data exceeds goal
No baseline data

4.2 Metering and Data Analysis

Data monitoring at Cosmos and Sinclair is undertaken through manually entering information from meters into data sheets which is then entered into Excel spreadsheets. These spreadsheets contain the metering information as well as other calculations and summary information such as graphs. The spreadsheets for data monitoring at Cosmos and Sinclair is outlined in Table 4.

For data analysis at Cosmos and Sinclair, they have both been assessed by the consulting company, Energetics, who developed an EMB for Cosmos energy data analysis and an energy snapshot for Sinclair. Cosmos and Sinclair also monitor their energy performance through their KPI spreadsheets.

Table 4: Data Monitoring for Cosmos and Sinclair Nickel Projects

	Cosmos	Sinclair
Power station Report	Powerhouse KPS includes information on gensets (gas and diesel usage, electricity generation and run hours) and electricity supply to feeder lines (Cosmos mine, Prospero mine, Plant, Village and Administration). Reported annually - Information is entered daily	Power Consumption Spreadsheet includes information on gensets (diesel usage, electricity generation and run hours) and electricity supply to feeder lines (treatment plant, powerline, village main and Byrnecut main). Information is entered once a month
Fuel pricing Spreadsheet	Includes information on cost pert litre ($AU and $US), average cost per litre and fuel costs Reported annually -Entered weekly	Includes information on cost pert litre ($AU and $US), average cost per litre and fuel costs Reported annually -Entered weekly
Diesel EOM	Includes information on the types of vehicles used and the amount of diesel usage for each. Reported monthly	Includes information on the types of vehicles used and the amount of diesel usage for each. Reported monthly.
Gas Trading Invoice	Includes information on gas delivered to site and costs Reported monthly	-
EMB	The EMB consolidates information from all of the data monitoring spreadsheets above, as well as information from the production report. The data is copied across from the original spreadsheets and calculations are automatically undertaken. The EMB information is entered monthly.	-

Potential problems that are apparent at both Cosmos and Sinclair which were identified from the current methods of data monitoring and data analysis are:

- Manually entered information – Increases the likelihood of incorrect information being entered through poor writing when recording readings, incorrectly entering information or recording readings by the wrong factor (Beggs 2009). For example, at Sinclair their diesel keys they have just manually allocated “LV” fuel to HV based on the assumption that it went into a generator, which may create an issue if audited by the government. The manual allocation may also account for Sinclair’s large LV readings at 24%). Another example of problems that exists with Sinclair’s data due to manually entered information is through their power station reports where the numbers differ between the spreadsheets that are written manually to those entered in the Excel spreadsheet, although these differences are quite marginal;

- Human Error – By manually entering the information it can increase the error in the data, for example at Sinclair an email was sent around from one of the electricians stating that the kWh reported in the spreadsheets was out by a factor of 10 due to a decimal point and there was only one month where the correct values were reported, where in fact the month that was thought to be correct was incorrect;
- Data not collected consistently – Leads to inaccurate readings for the month when the data is not collected consistently (e.g. Sinclair enters power station metering information once a month and it is either around the end of the month or the start of the following month);
- Lack of meters – Unable to monitor specific areas within the site due to the lack of meters. The problem is particularly prevalent at Sinclair where they only have four meters, and the underground and administration areas energy usage is determined through subtracting the other sub-meters from the powerline meter. It is vital that this is addressed as it assists in identifying significant power consumers and determining their load profiles;
- Time to collect information – The length of time taken to collect information may impact the data since it can take up to half an hour at Cosmos to collect just the genset information; and
- Structure of the EMB – The structure of the EMB led to problems of incorrect information being entered when the Diesel EOM’s and Power station Reports. These existed through not all of the information from the diesel EOM’s being entered so there was fuel that was not being accounted for and with the power station reports the values were not checked so information from reset meters was being used. Another problem that existed with the structure of the EMB is that when extra information was entered into the original spreadsheets (e.g. an extra ore body was added to the production report and extra gensets were added to the power station report) that information was not captured and the correct information was not carried across in the EMB due to the calculations within the EMB.

Another issue that was identified with data at Cosmos and Sinclair was discrepancies with diesel, which can be seen in the site Sankey diagram for Cosmos (Figure 6) and Sinclair (Figure 16). These diesel discrepancies are discussed in more detail in Sections 4.2.1 and 4.2.2 below.

4.2.1 Cosmos Nickel Project

The diesel discrepancies into the power station they are due to differences that were identified through the two different data monitoring spreadsheets (Powerhouse KPS and Diesel EOM) that recorded diesel for the power station. The Diesel EOM uses a powerhouse meter where they record readings. Recently that powerhouse meter has been faulty but they were able to determine readings for the diesel into the power station through using the opening balance of the fuel farm, doing the dips, subtracting the withdrawals for the months and then using the remaining value, attribute that towards the power station. The Powerhouse KPS spreadsheet uses the diesel values from the individual gensets and through summing those values it can be determined the total amount of diesel that enters the power station. The difference between the two monitoring spreadsheets is that the Powerhouse KPS spreadsheet under reports the diesel EOM by 151,088L.

4.2.2 Sinclair Nickel Project

The diesel discrepancies into the power station they are due to differences that were identified through the two different data monitoring spreadsheets (Power Consumption Spreadsheet and Diesel EOM) that recorded diesel for the power station. With the Diesel EOM spreadsheet the usage for diesel is estimated for the power station using the opening balance, doing the dips, subtracting the withdrawals for the month and attributing the remaining fuel to the power station. With the Power Consumption Spreadsheet, it is similar to how the readings are done at Cosmos, however they also use a pulse meters for the gensets. The maintenance personnel at Sinclair have little confidence in the accuracy of their figures and only report that way as a requirement of reporting to KPS. The difference in the two data monitoring spreadsheets is that the power station over reports how much diesel is used compared to the diesel EOMs by 17,264L.

5.0 OPPORTUNITIES

Following the identification of energy usage on site the next stage is to identify and assess the opportunities and then to recommend strategies for implementation.

5.1 Opportunity Analysis

The opportunities identified were compared based on a variety of criteria through a multi-criterion assessment and then all of the opportunities were compared based on financial savings and carbon abatement through a MAC curve.

5.1.1 Multi-criterion Analysis

A multi-criterion analysis (MCA) was created to assess the opportunities based on a variety of environmental, social, technical and financial criteria. The MCA (Appendix 4: Additional Information – MCA) was developed using Annandale and Lantze's guide (2000) on applying decision-aiding techniques and Taylor and Fletcher's (2005) guide on triple-bottom line assessments. For the environmental criteria, it included a version of XNA's risk register (Appendix 4: Additional Information – XNA Risk Register) which determined potential environmental risks that may be associated with the opportunity.

In order to compare the opportunities, the potential opportunities were separated into the categories of the potential opportunities are energy efficient technologies, alternative energy source opportunities, offsetting opportunities and metering and data collection equipment. The opportunities were then ranked and compared against opportunities within the same category.

A weighting to the criteria was taken into consideration during the ranking of the MCA which was based on XNA's preferences. XNA's weighting of criteria is presented in Table 5, and is weighted based on 1 being the most important to XNA and 10 being the least important to XNA.

Table 5: XNA's Weighting of Criteria

Criteria		Weighting 1-10 (Most Importance to least importance)
Environmental	XNA Risk Assessment	5
	Energy Savings (GJ)	4
	CO_2 Reduction (tCO_2)	4
Social	Human Health Impacts	5
	Local Involvement	6
	Improve Stakeholder Relations	6
	Lifestyle Change	7
	Difficulty of Project Implementation	3
Technical	Disturbance to Operations	2
	Training/Management Change	4
	Maintenance Requirement	2
	Safety Issues	1
	Productivity Impact	2
	Reliability	5
Financial	Net financial Benefits	1
	Estimated Payback Period	2

Energy efficient technologies were identified by personnel from different areas on site through workshops held by Energetics. These opportunities are still in the process of being assessed and the costs and energy savings presented in the MCA are being reviewed. Whilst many energy efficient ideas were identified during the workshops, the viable opportunities were the ones that were further assessed. Some of the opportunities that were identified as not viable due to lack of energy savings or high costs were power factor correction at Cosmos and Sinclair and connecting to the gas pipeline at Sinclair.

Power factor correction was identified as a possible energy saving by electricians at Sinclair. At Sinclair the power factor is 0.722 and at Cosmos it is 0.86. The power factor correction opportunity was not considered feasible as an electrical engineer at Cosmos determined that it would not achieve noticeable savings in fuel as it only reduces waste heat generated in wires and most power correction projects are undertaken for other reasons such as savings in the need for a larger distribution network capacity or the elimination of a utility tariff. For the gas pipeline at Sinclair, it would be possible to connect to the pipeline as it runs through the site and it would reduce diesel costs by generating electricity with gas energy. This opportunity was determined as not feasible as the fuel savings were marginal and the life of the mine was too short.

The technologies that were identified for further investigation and/or implementation at Cosmos and Sinclair are shown in figures 22 and 23 respectively. From these figures it can be seen that based on the criteria spinning reserve reduction for Cosmos and fuel additives for Sinclair are the most favourable opportunities for implementation, with timers in village rooms for Cosmos and campaigning primary crusher for Sinclair being the least favourable opportunities for implementation.

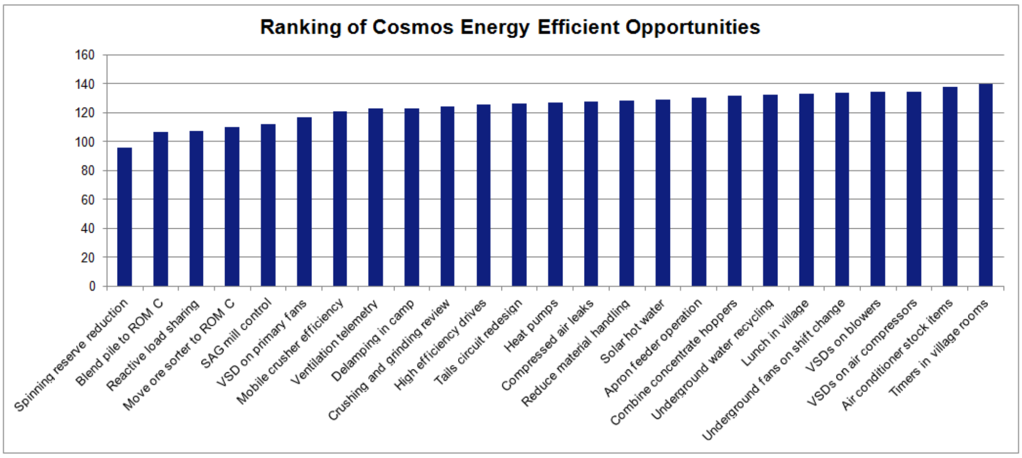

Figure 22: Ranking of Energy Efficient Opportunities for Cosmos

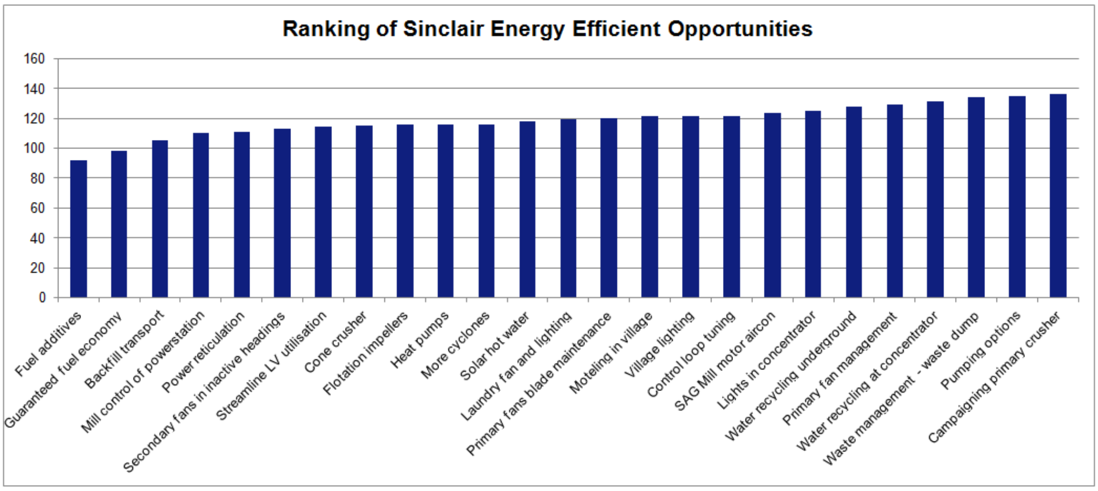

Figure 23: Ranking of Energy Efficient Opportunities for Sinclair

The alternative energy source opportunities that were identified for Cosmos and Sinclair were limited to ones that are not at the development stage, since it is vital for a mine site to have constant, reliable supply of energy. The energy source opportunities were sized to be able to supplement the energy produced by a 1MW generator. For solar PV, solar thermal and wind turbines local information (Leinster temperature, wind speed, peak sun hours and solar radiation) was used to determine the expected output using the methods outlined in PEC390 Energy Supply (Murdoch University unit).

From figure 24, the most favourable energy source opportunity is geothermal with the least favourable being waste gasification. It is important to note with both the most favourable and least favourable opportunities that they may not be viable as there are appears to minimal geothermal potential in the area and for waste gasification both Cosmos and Sinclair do not produce enough waste to generate electricity.

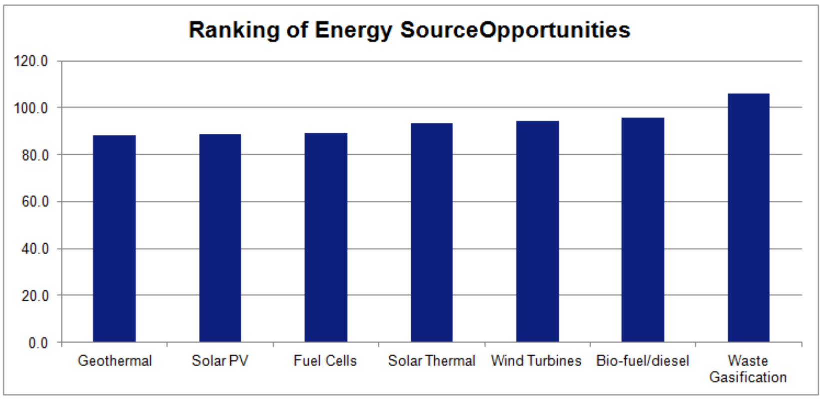

Figure 24: Ranking of Energy Source Opportunities

Offsetting opportunities was investigated as a potential opportunity to compensate for carbon emissions on site. The amount of offsetting units that would be bought were determined based on the amount of carbon emissions from a 1 MW generator. The ranking of the opportunities, as shown in figure 25, is similar, with forest sink being slightly less favourable than the other two opportunities due to slightly higher associated cost. It is important to note that with the impending carbon tax, carbon offsetting would not reduce the associated tax costs as it is seen as an additional voluntary option (Clean Energy Future *a* 2011).

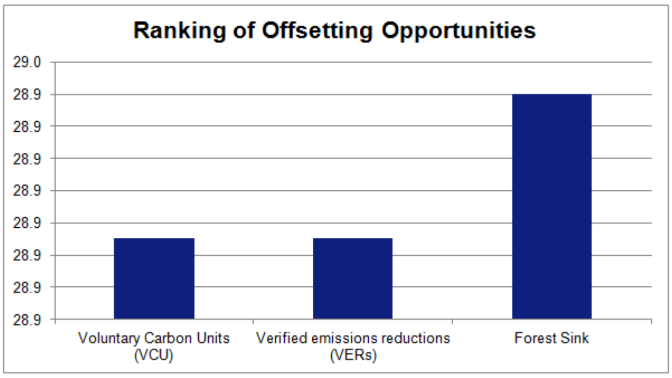

Figure 25: Ranking of Offsetting Opportunities

For the analysis of metering and data collection equipment, the results of the MCA is subjective. Due to the rankings for costs, carbon emissions and energy savings, the opportunities determined as more favourable were the opportunities, such as fuel management system, that had a direct saving. The other opportunities that had no direct energy savings but would result in better identification of energy use were the less favourable opportunities. Figure 26 and 27 show the metering and data collection opportunities for Cosmos and Sinclair respectively. For Sinclair, the opportunity of implementing more meters, which would be beneficial for energy analysis was not included in the analysis as the electricians said they were in the process of installing meters.

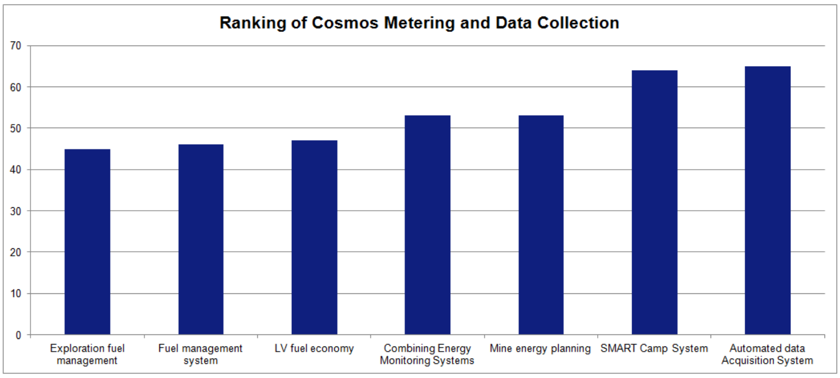

Figure 26: Ranking of Metering and Data Collection Opportunities for Cosmos

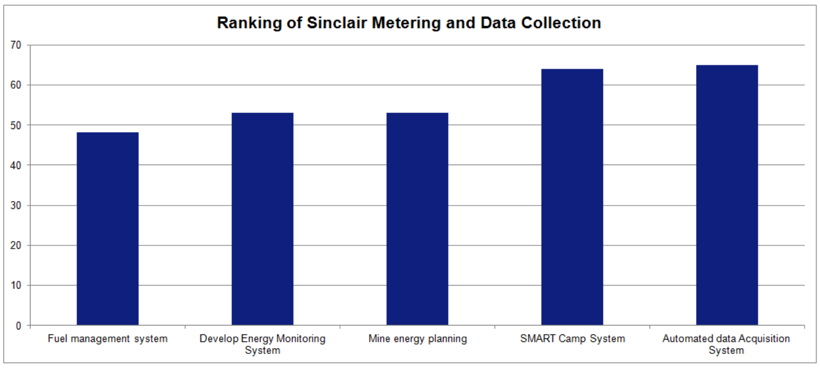

Figure 27: Ranking of Metering and Data Collection Opportunities for Sinclair

5.1.2 Marginal Abatement Cost Curve

A marginal abatement cost (MAC) curve (Appendix 4: Additional Information – MAC Curve) was developed to indicate which opportunities should be put into place based on their financial benefits and CO_2 reductions. The aim of the MAC curve is to show the relativity between the opportunities over a 4 year period. Figure 28 shows the MAC curve for the opportunities at Cosmos and figure 29 shows the MAC curve for the opportunities at Sinclair. From these graphs, the opportunities that have a greater width indicate that there is a greater amount of CO_2 that can be reduced, such as in figure 28 spinning reserve and in figure 29 fuel additives have high abatement potential. The height of the graph indicates the average cost of avoiding 1 ton of CO_2, with the opportunities below the horizontal axis indicating a net benefit over the lifecycle of the option. It should be noted that the opportunities with * (e.g. Solar PV *), have had the abatement potential divided by 100 due to the relative width compared to the other opportunities. These opportunities can still be compared financially though, since they are above the horizontal axis and indicate that they would have a longer payback period.

The four opportunities that have higher abatement potentials and a net benefit for Cosmos are:

1. Spinning reserve reduction – Capex of $45,000, reduce energy usage by 6.34% and GHG emissions by 5.93%;
2. Reactive load sharing – Capex of $360,000, reduce energy usage by 3.83% and GHG emissions by 3.58%;
3. Ventilation telemetry – Capex of $126,240, reduce energy usage by 2.40% and GHG emissions by 2.25%;
4. VSD on primary fans – Capex of $267,650, reduce energy usage by 1.24% and GHG emissions by 1.16%.

The four opportunities that have higher abatement potentials and a net benefit for Sinclair are:

1. Fuel additives – Capex of $45,000, reduce energy usage by 4.64% and GHG emissions by 4.64%;
2. More cyclones – Capex of $75,000, reduce energy usage by 2.93% and GHG emissions by 2.39%;
3. Guaranteed fuel economy – Capex of $0, reduce energy usage by 1.99% and GHG emissions by 1.99%;
4. Backfill transport – Capex of $0, reduce energy usage by 1.83% and GHG emissions by 1.83%.

These top four opportunities that were identified during the MAC curve analysis were also ranked highly in the MCA analysis with Cosmos' opportunities of spinning reserve reduction ranked 1st, reactive load sharing ranked 3rd, ventilation telemetry ranked 8th and VSD on primary fans ranked 6th; and Sinclair's opportunities of fuel additives ranked 1st, more cyclones ranked 11th, guaranteed fuel economy ranked 2nd and backfill transport ranked 3rd. While it is good that the results from the MAC curve and the MCA align, the opportunities for implementation are most likely to be from the opportunities identified in the MAC curve, since finance is a major driver in business. The MAC curve also indicates carbon abatement and with the impending carbon tax it provides significant reasons for implementing the opportunities that offer the biggest carbon abatement.

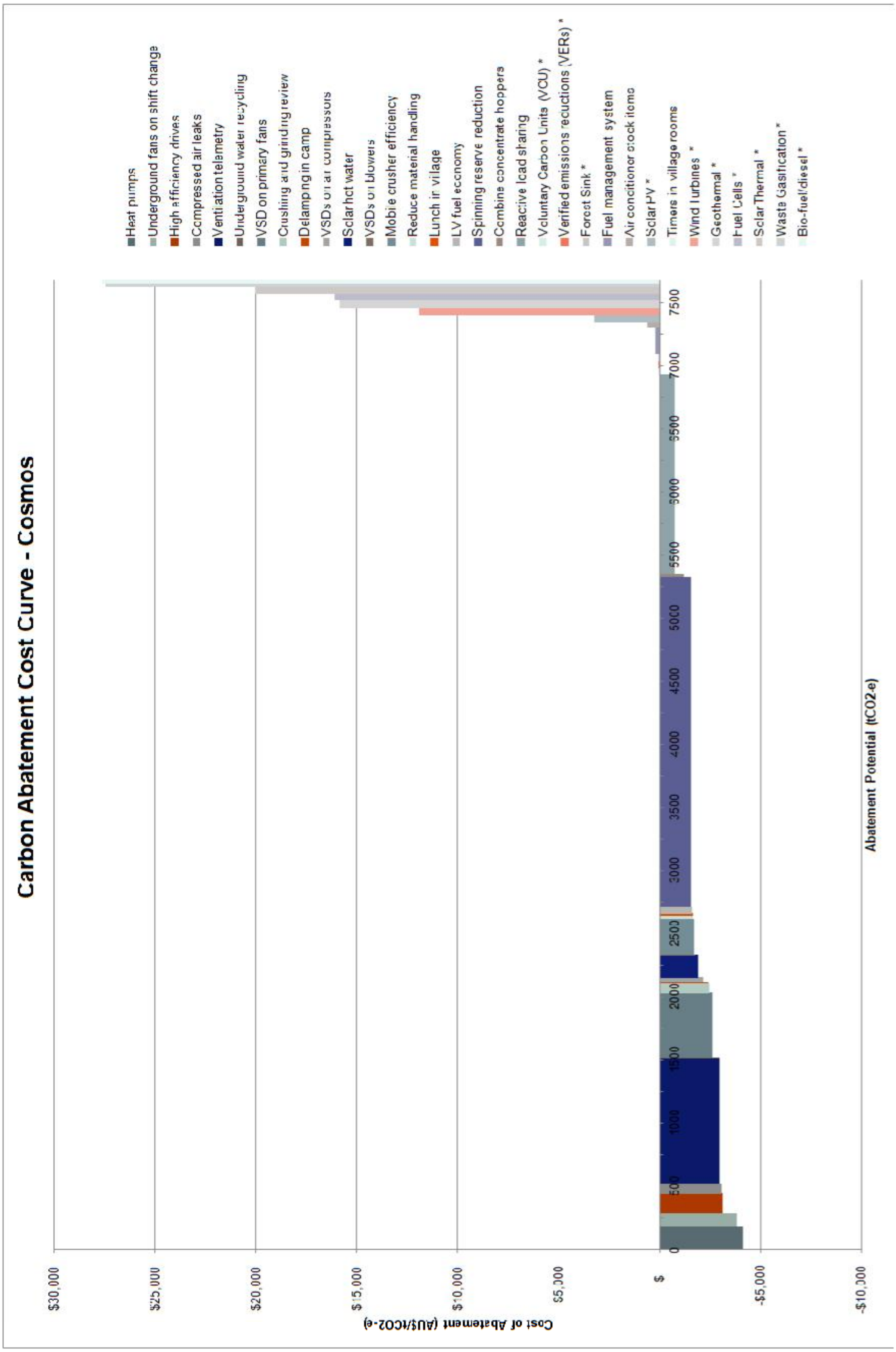

Figure 28: MAC Curve for Cosmos Opportunities

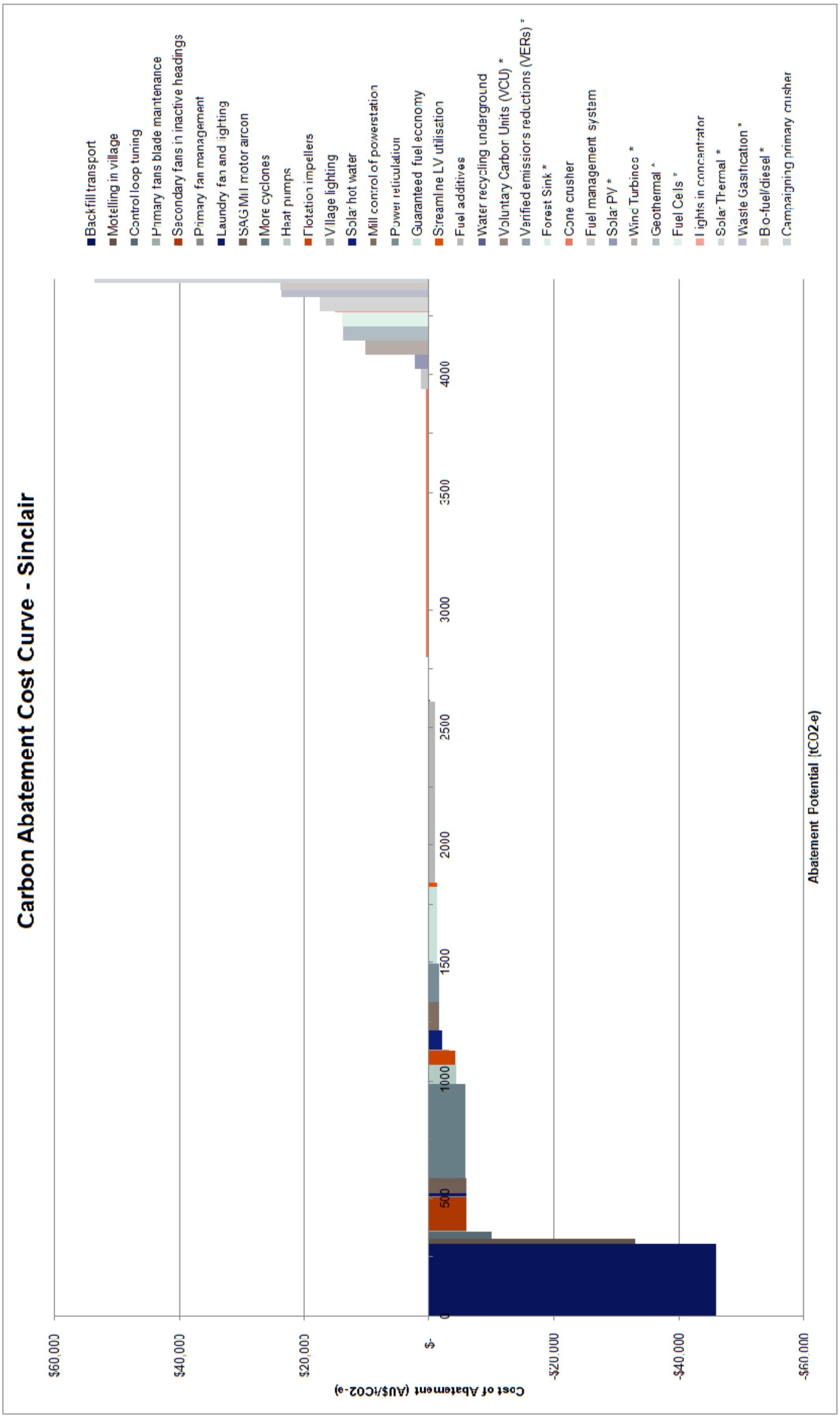

Figure 29: MAC Curve for Sinclair Opportunities

5.2 Implementation of Opportunities

5.2.1 Recommended Strategy

Based on the carbon abatement potential of the opportunities, all of the opportunities in the MAC curve (Figures 28 and 29) below the horizontal line are recommended to be implemented, however the top four opportunities identified in the opportunity analysis should be initially implemented to provide a significant reduction in carbon emissions.

For Cosmos, the top four initiatives were spinning reserve reduction, reactive load sharing, ventilation telemetry and VSD on primary fans. Currently all of the opportunities at Cosmos are still being investigated. If the top four opportunities were to be implemented it would result in a reduction of GHG emissions by 13% (5,688 $tCO_{2\text{-}e}$) and a reduction in energy usage by 14% (100,184 GJ). The capex requirement would be $799,890 however the overall savings for a four year period would be $9,759,167 and the payback period for the top four opportunities is less than 11 months.

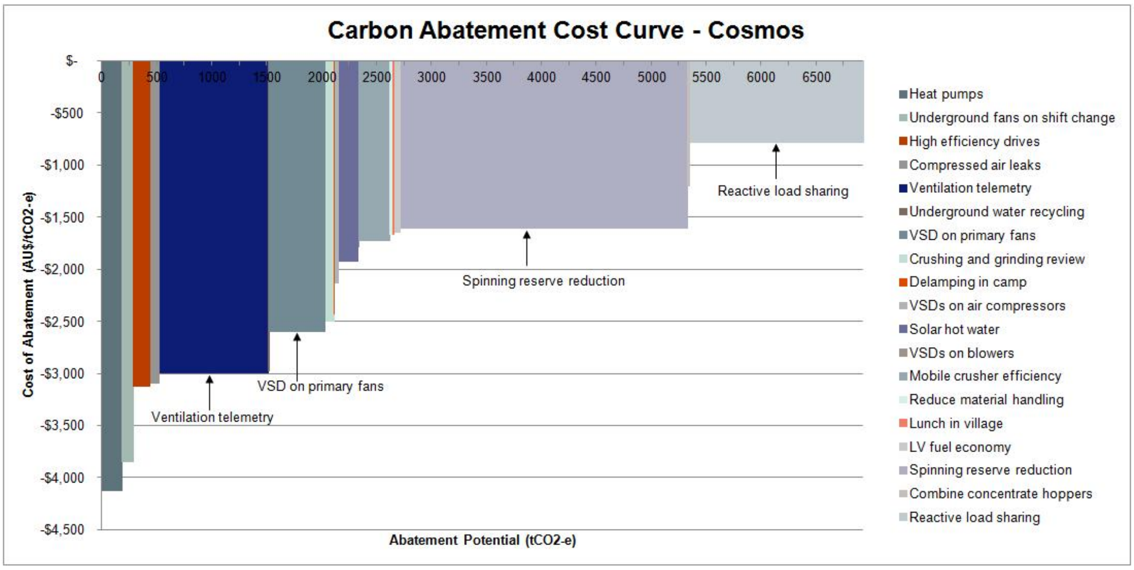

Figure 30: MAC Curve for recommended Cosmos Opportunities to be implemented

If all of the opportunities for Cosmos outlined in figure 30, with exception to solar hot water (since heat pumps have a shorter payback period and similar benefits) were implemented it would result in a reduction of GHG emissions by 16% (6,998 $tCO_{2\text{-}e}$) and a reduction in energy usage by 17% (121,203 GJ). The capex requirement would be $2,021,514 however the overall savings for a four year period would be $14,307,011. All of the opportunities have a payback period of less than 2 years, except combine concentrate hoppers which has a payback period of 2.46 years.

For Sinclair the opportunities were fuel additives, more cyclones, guaranteed fuel economy and backfill transport. Of these opportunities, guaranteed fuel economy has been approved for implementation and more cyclones is currently in progress. Other opportunities that are in progress or approved for implementation at Sinclair are control loop tuning, secondary fans in inactive headings and primary fan management. If the top four opportunities were to be implemented, and including the opportunities that are currently being implemented, it would result in a reduction of GHG emissions by 12% (1,982 $tCO_{2\text{-}e}$) and a reduction in energy usage by 13% (30,384 GJ). The capex requirement would be $132,000 however the overall savings for a four year period would be $18,735,861. The payback period for the top four opportunities is less than 3 months.

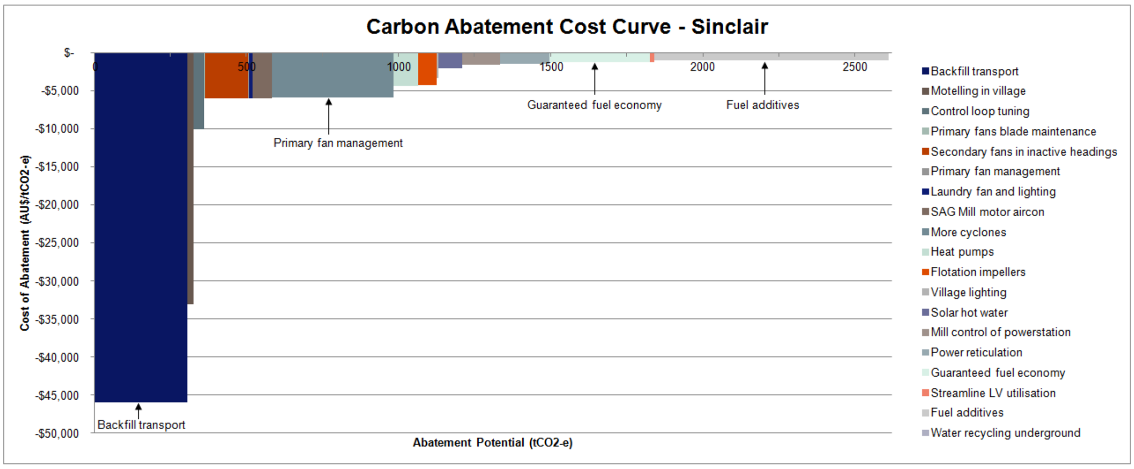

Figure 31: MAC Curve for recommended Cosmos Opportunities to be implemented

If all of the opportunities for Sinclair outlined in figure 31, with exception to solar hot water (since heat pumps have a shorter payback period and similar benefits) were implemented it would result in a reduction of GHG emissions by 15% (2,531 $tCO_{2\text{-}e}$) and a reduction in energy usage by 17% (39,467 GJ). The capex requirement would be $445,580 however with modelling in the village was implemented it would save $534,900 resulting in a positive difference of $89,320. The overall savings for a four year period would be $20,925,667. All of the opportunities have a payback period of less than 2 years, except water recycling underground which has a payback period of 3.97 years.

5.2.2 Carbon Neutrality Strategy

As discussed in the project background the second step for reducing dependency on fossil fuels would be to look towards carbon neutrality through the implementation of alternative energy sources such as renewable technologies and through buying carbon offsets. An important part of achieving carbon neutrality would be through raising awareness and implementing energy efficient technologies which would not only reduce energy use but reduce the amount of carbon emissions that need to be abated through renewable technologies or carbon offsets which would also reduce the capex. Figure 32 illustrates this strategy of initially having avoidance of energy usage, then looking towards energy efficient behaviours, before the implementation of renewable technologies or buying carbon offsets.

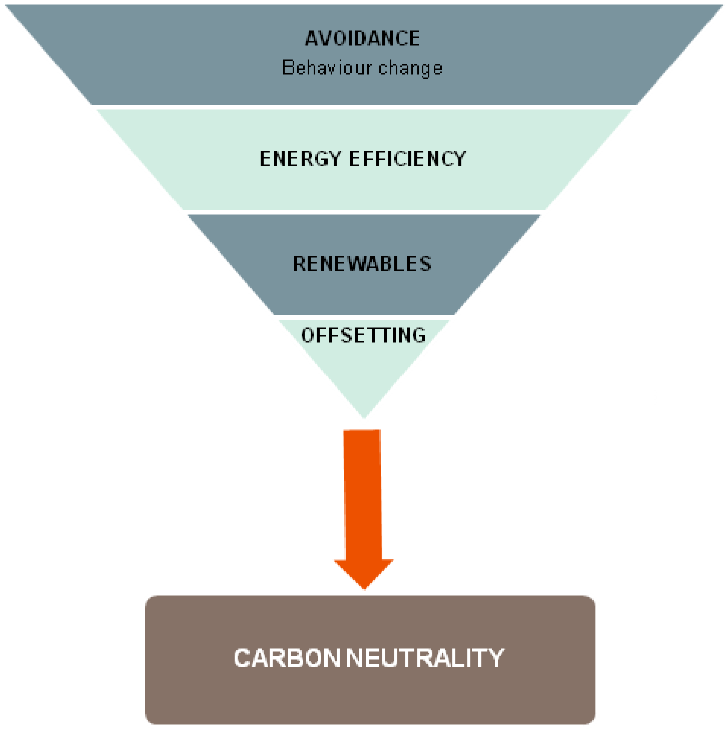

Figure 32: Strategy for Carbon Neutrality (Maribyrymong City Council 2008)

Based on this strategy for moving towards carbon neutrality, if Cosmos and Sinclair were to firstly implement all of the energy efficiency opportunities outlined in the Recommended Strategy before looking towards implementing renewable or offsetting it would reduce the capex and payback periods making the potential for moving towards carbon neutrality more viable. For Cosmos and Sinclair to become carbon neutral it would cost $465 million and $155 million respectively. Taking into consideration the net benefits of implementing the energy efficient technologies over a four year period, it would then reduce the costs for Cosmos to $451 million with a payback period of 14 years and for Sinclair to $134 million with a payback period of 7 years. The costs were determined using the costs from solar PV since it was the cheapest renewable technology identified in the Option Analysis and included the costs saved and incurred by paying out the contractor of the generators. If carbon tax was taken into consideration also, it would result in further savings for Cosmos and Sinclair of

$2,557,140 and $971,244 respectively over the 3 year period that the carbon tax is to be implemented (Clean Energy Future b 2011).

For implementing offsetting options the capex would be less than what would be required for implementing renewable technologies, however there would be no long term financial benefits and financial benefits from the carbon tax since it is seen as a voluntary option. For implementing either of the cheaper offsetting options identified in the Option Analysis over a four year period it would cost $741,200 for Cosmos and $281,520 for Sinclair.

If Cosmos and Sinclair were to become carbon neutral, without implementing any energy efficient technologies, the capex requirement would be significantly larger and result in longer payback periods. For Cosmos and Sinclair, to become carbon neutral using renewable technologies (solar PV) it would cost $557 million with a payback of 15 years and $185 million with a payback of 8 years respectively. Taking into consideration the carbon tax it would result in savings for Cosmos and Sinclair of $3,040,002 and $1,145,883 respectively. For implementing either of the cheaper offsetting options identified in the Option Analysis over a four year period it would cost $881,160 and $332,140 respectively. The percentage difference in costs between implementing a carbon neutral strategy for renewable technologies with and without using energy efficiency initially for Cosmos is 19% ($107 million) and for Sinclair 28% ($51 million).

A problem with implementing a carbon neutral strategy for Cosmos and Sinclair is that the long payback periods exceed the current expected lifetime of the mines. If more ore bodies are found at Cosmos or Sinclair, which would increase the life of the mine, it may become feasible for XNA to look towards implementing renewable technologies.

5.2.3 Metering and Data Collection Strategy

The metering and data collection strategy for Cosmos and Sinclair would be to initially look towards improving the current data analysis systems through developing a spreadsheet or database that combines all of the information from KPIs, the EMB and GHG emissions rather than triple handling the information. For Cosmos' current EMB it is important that data validation checks are undertaken to ensure that all of the information is carried across properly, and potentially the spreadsheet could be altered to have a cell that checked for data abnormalities.

For Sinclair, it is vital that Sinclair install their extra meters and begin recording so that they better capture the energy flows around the site. Sinclair would also benefit from more frequent and consistent meter reading, similar to what is currently done at Cosmos where the meters are read once a day.

A fuel management system would be beneficial for both Cosmos and Sinclair to ensure that fuel keys were being entered correctly and reduce spills which would result in total energy savings of 3,100 GJ for Cosmos and 1,240 GJ for Sinclair. There would be a negative net benefit for the implementation of the systems, which may make it difficult to create a business case for implementing the system, since it would cost Cosmos $40,256 and Sinclair $116,102 over a four year period.

Another issue that is currently being addressed onsite, but it is important that it is carried through, is identifying the diesel discrepancies in the Diesel EOM and Power station report and the unaccounted power between the meters and sub-meters. The diesel discrepancies are believed to be more accurate from the information in the Diesel EOM however, it needs to be further investigated for the difference in the Power Station report. For Cosmos it would be to further investigate why the meters were faulty and for Sinclair it would be to further investigate why they have little confidence in their power station fuel meters, particularly since they are reporting these fuel values to KPS.

In the future it would be beneficial, on an analysis basis, for both Cosmos and Sinclair to look towards a automated data acquisition system, as analysed in the opportunity analysis. By moving towards an automated data acquisition system it would help to better identify energy flows around site, it would reduce the current problems with the data monitoring system that were identified in the metering and data collection analysis, such as inconsistent data collection, time taken to collect information and human error.

6.0 EEO REPORTING

As per the requirements of the EEO program, XNA is required to submit an annual report for the results from their 2010/2011 energy analysis. These reports encompass energy efficient opportunities that were identified at both Cosmos and Sinclair, and do not include the opportunities identified for renewable energy sources, offsetting opportunities and metering and data analysis equipment. For their second report XNA is only required to submit a public EEO report by 31 December 2011, which is required to be available through their website and is shown in Table 6.

Table 6: XNA's Public EEO Report

PUBLIC		Total Number of Opportunities	Estimated energy savings per annum by payback period (GJ)						Total estimated energy savings per annum (GJ)
			0 – < 2 years		2 – ≤ 4 years		> 4 years		
			No of Opps	GJ	No of Opps	GJ	No of Opps	GJ	
Status of opportunities identified to an accuracy of better than or equal to ±30%									
Business Response	Implemented								0
	Implementation Commenced	1	1	2,472					2472
	To be Implemented	1	1	4,751					4751
	Under Investigation	17	14	83,184	1	457	2	679	84320
	Not to be Implemented								0
Outcomes of assessment	Total Identified	19	16	90,406	1	457	2	679	91543
Status of opportunities identified to an accuracy of worse than ±30%									
Business Response	Implemented	3	2	4,378	1	175			4554
	Implementation Commenced	1	1	348					348
	To be Implemented	1					1	0	0
	Under Investigation	22	17	61,284	4	23,512	1	-8,365	76431
	Not to be Implemented	2	2	3,620					3620
Outcomes of assessment	Total Identified	29	22	69,631	5	23,687	2	-8,365	84953

XNA is required to submit their second government report for the 2012/2013 analysis by 31 December 2013. The government report is submitted to DRET and includes more detailed information that the public report. The structure of the government report has been included (Table 7) to illustrate the differences in reporting requirements from the public and government report. The public EEO report provides a summary of the opportunities identified based on their accuracy (<30% or >30%). The information includes the number of opportunities, the estimated energy savings and the payback period for the opportunities. The government EEO report expands on this information by specifying the energy type of the opportunities and includes the annual net financial benefits of implementing the opportunities.

Table 7: XNA's Government EEO Report

GOVERNMENT		Annual Net Value of Savings arising from Opportunities by Payback Period and Fuel Type				
		No of Opps	Energy type	Payback 0<2, 2–4 or 4+ years	Annual net energy savings (GJ)	Annual net financial benefits ($)
Status of opportunities assessed to an accuracy of better than or equal to ±30%						
Business Response	Implementation Commenced	1	Electricity	0<2 years	2,472	$851,341
	To be Implemented	1	Diesel	0<2 years	4,751	$423,391
	Under Investigation	3	Diesel	0<2 years	5,132	$611,421
	Under Investigation	1	Diesel/gas	0<2 years	45,987	$4,201,930
	Under Investigation	10	Electricity	0<2 years	32,065	$5,295,037
	Under Investigation	1	Electricity	2-4 years	457	$31,285
	Under Investigation	2	Electricity	4+ years	679	-$32,231
Total opportunities identified		19			91,543	$11,382,174
Status of opportunities assessed to an accuracy of worse than ±30%						
Business Response	Implemented	1	Diesel	0<2 years	4,378	$13,974,199
	Implemented	2	Electricity	2-4 years	175	$391
	Implementation Commenced	1	Electricity	N/A	348	$654,884
	To be Implemented	1	Diesel	N/A	0	-$62,580
	Under Investigation	11	Electricity	0<2 years	19,560	$4,749,542
	Under Investigation	3	Electricity	4+ years	20,412	-$1,616,617
	Under Investigation	1	Electricity	N/A	(8,365)	-$3,681,390
	Under Investigation	5	Diesel	0<2 years	1,071,341	$13,970
	Under Investigation	1	Diesel	4+ years	(40,256)	$3,100
	Under Investigation	1	Diesel/Gas	0<2 years	27,754	$1,251,124
	Not to be Implemented	2	Diesel	0<2 years	3,620	$1,665,151
Total opportunities identified		29			1,098,968	$16,951,774

7.0 CONCLUSION

The purpose of this report was to analyse the energy usage at XNA's Cosmos and Sinclair Nickel operations and then to identify and evaluate energy efficient opportunities as required by the EEO program. In addition, the GHGs emitted by the sites were also analysed to determined what would be required to move the sites towards carbon neutrality.

Cosmos and Sinclair's energy usage was determined using the available metering and data analysis information that was obtained through site visits to Cosmos and Sinclair. The carbon emissions from both Cosmos and Sinclair were also analysed for determining what would be required for moving the sites towards carbon neutrality. The energy usage was analysed using graphical representations and Sankey diagrams to illustrate energy flows. During the analysis of Cosmos' and Sinclair's energy usage the metering and data analysis information, which included Cosmos' EMB, was also analysed to determine how these systems could be improved.

Following the data analysis, potential energy efficient opportunities were identified as required by the EEO program through engaging with on-site personnel, renewable energy source and offsetting opportunities were investigated for moving the sites towards carbon neutrality, and improvements to the current metering and data analysis equipment were also analysed. These opportunities were then assessed of their feasibility for implementation through a multi-criterion analysis and marginal abatement cost curve. Four opportunities were identified at Cosmos and Sinclair based on their high abatement potentials and net benefits which were spinning reserve reduction, reactive load sharing, ventilation telemetry and VSD on primary fans for Cosmos, and fuel additives, more cyclones, guaranteed fuel economy and backfill transport for Sinclair.

Three strategies were outlined which included the strategy recommended for implementation, a strategy for moving towards carbon neutrality and a strategy for metering and data analysis. The recommended strategy, which included the top four initiatives, would reduce the energy usage and carbon emissions for both sites and also provide a net benefit for their implementation. The carbon neutrality strategy was determined to have high capex and payback periods and it would be difficult to create a business case for the move towards carbon neutrality based on the current life of the mines. A few opportunities were outlined for the metering and data analysis strategy since better metering and data analysis does not result in any direct energy savings so initial opportunities with no costs were recommended with the recommendation for looking in the future to implementing better data analysis systems.

Finally, the public and government EEO reports for XNA were included as per their reporting requirements for EEO for the 2010/2011 period which outlined the energy efficient opportunities that were identified and summarised the potential energy savings and net benefits from those opportunities.

8.0 RECOMMENDATIONS

Since the EEO program is an ongoing process, Cosmos and Sinclair will need to continue to assess their energy usage, to identify potential energy efficient opportunities, to determine if the options are viable for implementation based on the energy savings and the net financial benefits and report annually to DRET. Further work needs to be undertaken at both Cosmos and Sinclair on the initial opportunities that were identified to determine their viability for implementation, which is currently being re-analysed by Energetics and then requires analysis by XNA personnel.

To ensure that there is better energy data analysis, Sinclair will need to ensure that their extra meters are fitted and more frequent and consistent metering reading is undertaken.

Both Cosmos and Sinclair would benefit from developing a spreadsheet or database that incorporates the energy information for calculating their KPI information, their EMB and their GHG emissions to prevent triple handling of information and ensures that the calculations are more consistent. For Cosmos, two problems that were identified with their EMB, was that the final diesel value calculated in the EMB didn’t align with the Diesel EOM often due to the reconciliation value, and the total kWh for the gensets were too high when the meters were reset in the power station report. This problem could be overcome, to prevent inaccurate information being entered, by manually checking if the fuel values aligned in the EMB and the diesel EOM and if the genset efficiency which indicated if the meter was reset if the values were too high or through entering in a cell in the spreadsheet to check for abnormalities in the spreadsheet.

While the potential of moving Cosmos and Sinclair to carbon neutrality was identified as not feasible due to financial reasons and the life time of the mine as illustrated in the table below, further research could be done since renewable technologies are continually reducing in price and for the potential of further ore bodies being found on-site which would increase the life of the mine and mean the move to carbon neutrality would be financially beneficial for XNA.

	Site	Description	Capex	Payback period	Considerations
Carbon Neutrality Strategy	Cosmos	Implementing energy efficiency opportunities first, then implementing renewable technologies (Solar PV – cheapest option)	$451 million	≈14 years	Mine expected to be running in 2017 (6 years)
	Cosmos	Implementing energy efficiency opportunities first, then implementing offsetting opportunities (cheapest option)	$741,200		Voluntary investment
	Sinclair	Implementing energy efficiency opportunities first, then implementing renewable technologies (Solar PV – cheapest option)	$134 million	≈7 years	Life of mine 2 years
	Sinclair	Implementing energy efficiency opportunities first, then implementing offsetting opportunities (cheapest option)	$281,520	-	Voluntary investment

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10.0 APPENDICES

10.1 Energy Costs

Throughout the 2010/2011 reporting period there have been increases with the energy costs for diesel and natural gas. Figure 33 shows a slight rise in diesel costs with an increase of $0.10/L, and Figure 34 shows a significant rise in the cost of natural gas of $2.23/GJ for the year. Despite the significant rise in natural gas, the overall unit cost for electricity cost for Cosmos was lower than Sinclair, as shown in Figure 35, with an overall increase over the year of $0.03/kWh for Cosmos and $0.02/kWh for Sinclair.

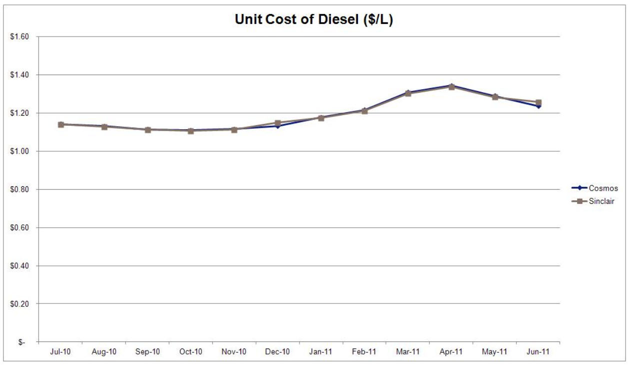


Figure 33: Variation in Unit Cost of Diesel over 2010/2011 Period

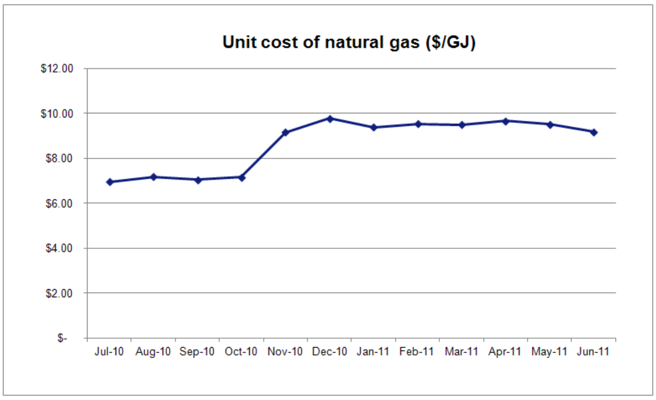


Figure 34: Variation in Unit Cost of Natural Gas over 2010/2011 Period

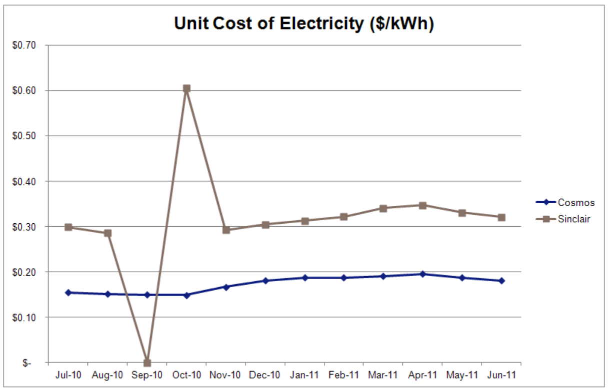
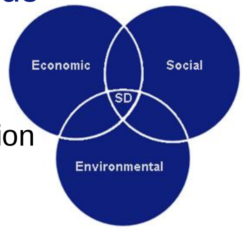


Figure 35: Variation in Unit Cost of Electricity (energy only) for Cosmos and Sinclair over 2010/2011 Period

10.2 Xstrata Sustainable Development (SD) Standards



Sustainable development (SD) can be defined as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Brundtland Commission 1987). We can also say it is where the economic, social and environmental needs are met. Xstrata has 17 SD standards:

Table 8: Xstrata Sustainable Development Standards

Xstrata Standard	Description
Std 1: Leadership, Strategy and Accountability	Proactive leadership, SD incorporated at all levels of organisation, Performance plans for all employees, Defined roles and responsibilities
Std 2: Planning and Resources	Annual SD plans: consultation, targets, documented, reviewed quarterly.
Std 3: Behaviour, Awareness and Competency	All employees have identified roles and are aware of SD and safety responsibilities.
Std 4: Communication and Engagement	Internal and external stakeholders are to be involved in the development and review of the SD program. Group Sustainability Report to be prepared annually.
Std 5: Risk and Change Management	SD risks identified, including during changes in operations.
Std 6: Catastrophic Hazards	Assess, plan and review Catastrophic changes in operations
Std 7: Legal Compliance and Document Control	Keep up to date with legal requirements.
Std 8: Operational Integrity	Maintain operational integrity of plant, equipment, structures, processes and protective systems, including assessments and reviews.
Std 9: Health and Occupational Hygiene	Health assessments (pre-employment and throughout employment), hazard identification and appropriate health care for employees
Std 10: Environment, Biodiversity and Landscape Functions	Impact assessment, minimise harm, conserve resources, education and awareness programs.
Std 11: Contractors, Suppliers and Partners	SD must be considered when selecting Contractors – SD targets and responsibilities are to be specified. Consider local contractors as part of sustainable community development.
Std 12: Social and Community Engagement	Social involvement plan and community strategy to be developed to enhance socio-economic capability and sustainability
Std 13: Life Cycle Management – Projects and Operations	SD to be considered during all phases of projects, including exploration, operation and mine closure. SD risks from new plant equipment & infrastructure to be assessed.
Std 14: Product Stewardship	SD impacts from Xstrata's products and services to be assessed, including recycling and disposal.
Std 15: Incident Management	Incident management via investigation, corrective actions, documentation and communication
Std 16: Monitoring and Review	Annual management review of all SD plans and policies, SD inspections and audits.
Std 17: Emergencies, Crises and Business Continuity	HSEC emergency and business crises planned for, people trained in emergency response

10.3 Australia's Energy Usage

Compared to other OECD countries, Australia's emissions per person is significantly higher and even more so when compared to the World Average, as shown in Figure 36. When assessing industries within Australia (Figure 37), mining does account for a reasonable percentage of emissions. In terms of energy demand, in Western Australia, mining is one of the higher demanding sectors which is evident in Figure 38.

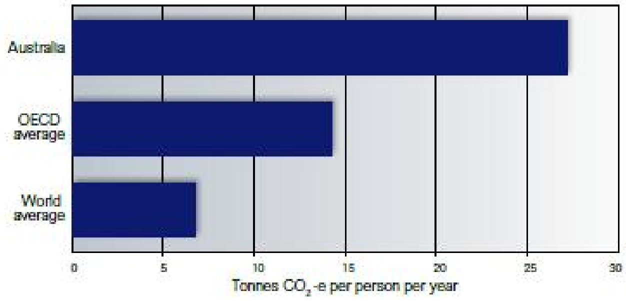


Figure 36: Australia and OECD & World Averages per capita GHG emissions 2005 (Garnaut 2008)

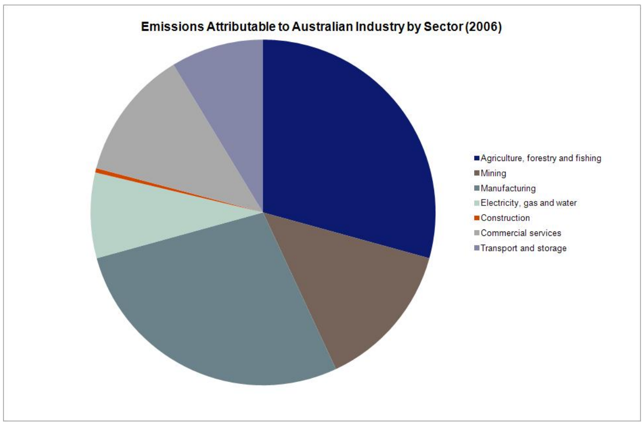


Figure 37: Emissions Attributable to Australian Industry by Sector 2006 (Garnaut 2008)

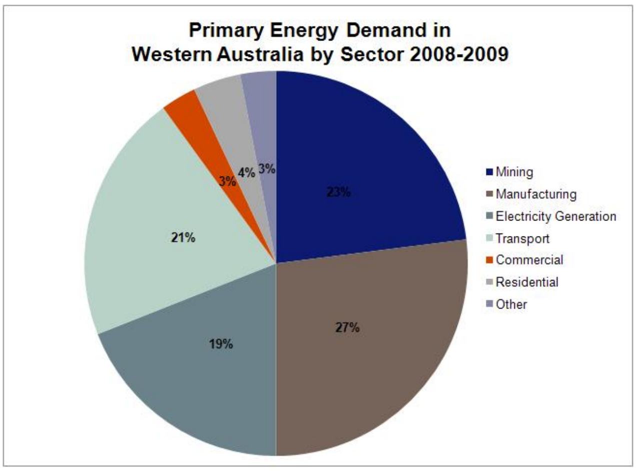


Figure 38: Primary Energy Demand in WA by Sector 2008-2009 (Office of Energy 2011)

10.4 Additional Information

Attached CD includes Excel spreadsheets:

- MAC Curve;
- MCA; and
- XNA Risk Register.